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<p>(54) Title: CHIMERIC IMMUNOGENS (57) Abstract Multimeric hybrid genes encoding the corresponding chimeric protein comprise a gene sequence coding for an antigenic region of a protein from a first pathogen linked to a gene sequence coding for an antigenic region of a protein from a second pathogen. The pathogens particularly are parainfluenza virus (PIV) and respiratory syncytial virus (RSV). A single recombinant immunogen is capable of protecting infants and similar susceptible individuals against diseases caused by both PIV and RSV.</p>		

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CHIMERIC IMMUNOGENSFIELD OF INVENTION

5 The present invention relates to the engineering and expression of multimeric hybrid genes containing sequences from the gene coding for immunogenic proteins or protein fragments of numerous pathogens.

BACKGROUND TO THE INVENTION

10 The advantage of the approach taken by the present invention is to produce single immunogens containing protective antigens from a range of pathogens. Such chimeras greatly simplify the development of combination vaccines, in particular, with the view ultimately to
15 produce single dose multivalent vaccines. Multivalent vaccines are currently made by separately producing pathogens and/or their pertinent antigens and combining them in various formulations. This is a labour intensive, costly and complex manufacturing procedure.
20 In contrast, the availability of a single immunogen capable of protecting against a range of diseases would solve many of the problems of multivalent vaccine production. Several chimeric immunogens of the type provided herein may be combined to decrease the number of
25 individual antigens required in a multivalent vaccine.

 Human Parainfluenza virus types 1,2,3 and Respiratory syncytial virus types A and B are the major viral pathogens responsible for causing severe respiratory tract infections in infants and young
30 children. It is estimated that, in the United States alone, approximately 1.6 million infants under one year of age will have a clinically significant RSV infection each year and an additional 1.4 million infants will be infected with PIV-3. Approximately 4000 infants less
35 than one year of age in the United States die each year from complications arising from severe respiratory tract disease caused by infection with RSV and PIV-3. The WHO

and NIALD vaccine advisory committees ranked RSV number two behind HIV for vaccine development while the preparation of an efficacious PIV-3 vaccine is ranked in the top ten vaccines considered a priority for vaccine
5 development.

Safe and effective vaccines for protecting infants against these viral infections are not available and are urgently required. Clinical trials have shown that formaldehyde-inactivated and live-attenuated viral
10 vaccines failed to adequately protect vaccinees against these infections. In fact, infants who received the formalin-inactivated RSV vaccine developed more serious lower respiratory tract disease during subsequent natural RSV infection than did the control group. [Am. J.
15 Epidemiology 89, 1969, p.405-421; J. Inf. Dis. 145, 1982, p.311-319]. Furthermore, RSV glycoproteins purified by immunoaffinity chromatography using elution at acid pH induced immunopotential in cotton rats. [Vaccine,
20 10(7), 1992, p.475-484]. The development of efficacious PIV-3 and RSV vaccines which do not cause exacerbated pulmonary disease in vaccinees following injection with wild-type virus would have significant therapeutic implications. It is anticipated that the development of
25 a single recombinant immunogen capable of simultaneously protecting infants against diseases caused by infection with both Parainfluenza and Respiratory syncytial viruses could significantly reduce the morbidity and mortality caused by these viral infections.

It has been reported that a protective response
30 against PIV-3 and RSV is contingent on the induction of neutralizing antibodies against the major viral surface glycoproteins. For PIV, these protective immunogens are the HN protein which has a molecular weight of 72 kDa and possesses both hemagglutination and neuraminidase
35 activities and the fusion (F) protein, which has a molecular weight of 65 kDa and which is responsible for

both fusion of the virus to the host cell membrane and cell-to-cell spread of the virus. For RSV, the two major immunogenic proteins are the 80 to 90 kDa G glycoprotein and the 70 kDa fusion (F) protein. The G and F proteins are thought to be functionally analogous to the PIV HN and F proteins, respectively. The PIV and RSV F glycoproteins are synthesized as inactive precursors (FO) which are proteolytically cleaved into N-terminal F2 and C-terminal F1 fragments which remain linked by disulphide bonds.

Recombinant surface glycoproteins from PIV and RSV have been individually expressed in insect cells using the baculovirus system [Ray et al., (1989), Virus Research, 12: 169-180; Coelingh et al., (1987), Virology, 160: 465-472; Wathen et al., (1989), J. of Inf. Dis. 159: 253-263] as well as in mammalian cells infected with recombinant poxviruses [Spriggs, et al., (1987), J. Virol. 61: 3416-3423; Stott et al., (1987), J. Virol. 61: 3855-3861]. Recombinant antigens produced in these systems were found to protect immunized cotton rats against live virus challenge. More recently, hybrid RSV F-G [Wathan et al., (1989), J. Gen Virol. 70: 2625-2635; Wathen, published International Patent application WO 89/05823] and PIV-3 F-HN [Wathen, published International Patent Application WO 89/10405], recombinant antigens have been engineered and produced in mammalian and insect cells. The RSV F-G hybrid antigen was shown to be protective in cotton rats [Wathan et al., (1989), J. Gen. Virol. 70: 2637-2644] although it elicited a poor anti-G antibody response [Connors et al., (1992), Vaccine 10: 475-484]. The protective ability of the PIV-3 F-HN protein was not reported in the published patent application. These antigens were engineered with the aim to protect against only the homologous virus, that is either RSV or PIV-3. However, it would be advantageous and economical to engineer and produce a single

recombinant immunogen containing at least one protective antigen from each virus in order simultaneously to protect infants and young children against both PIV and RSV infections. The chimeric proteins provided herein
5 for such purpose also may be administered to pregnant women or women of child bearing age to stimulate maternal antibodies to both PIV and RSV. In addition, the vaccine also may be administered to other susceptible individuals, such as the elderly.

10 SUMMARY OF INVENTION

In its broadest aspect, the present invention provides a multimeric hybrid gene, comprising a gene sequence coding for an antigenic region of a protein from a first pathogen linked to a gene sequence coding for an
15 antigenic region of a protein from a second pathogen and to a chimeric protein encoded by such multimeric hybrid gene. Such chimeric protein comprises an antigenic region of a protein from a first pathogen linked to an antigenic region of a protein from a second pathogen.

20 The first and second pathogens generally are selected from bacterial and viral pathogens and, in one embodiment, may both be viral pathogens. Preferably, the first and second pathogens are selected from those causing different respiratory tract diseases, which may
25 be upper and lower respiratory tract diseases. In a preferred embodiment, the first pathogen is parainfluenza virus and the second pathogen is respiratory syncytial virus. The PIV protein particularly is selected from PIV-3 F and HN proteins and the RSV protein particularly
30 is selected from RSV G and F proteins. Another aspect of the invention provides cells containing the multimeric hybrid gene for expression of a chimeric protein encoded by the gene. Such cells may be bacterial cells, mammalian cells, insect cells, yeast cells or fungal
35 cells. Further, the present invention provides a live vector for antigen delivery containing the multimeric

hybrid gene, which may be a viral vector or a bacterial vector, and a physiologically-acceptable carrier therefor. Such live vector may form the active component of a vaccine against diseases caused by multiple pathogenic infections. Such vaccine may be formulated to be administered in an injectable form, intranasally or orally.

In an additional aspect of the present invention, there is provided a process for the preparation of a chimeric protein, which comprises isolating a gene sequence coding for an antigenic region of a protein from a first pathogen; isolating a gene sequence coding for an antigenic region of a protein from a second pathogen; linking the gene sequences to form a multimeric hybrid gene; and expressing the multimeric hybrid gene in a cellular expression system. Such cellular expression system may be provided by bacterial cells, mammalian cells, insect cells, yeast cells or fungal cells. The chimeric protein product of gene expression may be separated from a culture of the cellular expression system and purified.

The present invention further includes a vaccine against diseases caused by multiple pathogen infections, comprising the chimeric protein encoded by the multimeric hybrid gene and a physiologically-acceptable carrier therefor. Such vaccine may be formulated to be administered in an injectable form, intranasally or orally.

The vaccines provided herein may be used to immunize a host against disease caused by multiple pathogenic infections, particularly those caused by a parainfluenza virus and respiratory syncytial virus, by administering an effective amount of the vaccine to the host. As noted above, for human PIV and RSV, the host may be infants and young children, pregnant women as well as those of a

child-bearing age, and other susceptible persons, such as the elderly.

The chimeric protein provided herein also may be used as a diagnostic reagent for detecting infection by a plurality of different pathogens in a host, using a suitable assaying procedure.

It will be appreciated that, while the description of the present invention which follows focuses mainly on a chimeric molecule which is effective for immunization against diseases caused by infection by PIV and RSV, nevertheless the invention provided herein broadly extends to any chimeric protein which is effected for immunization against diseases caused by a plurality of pathogens, comprising an antigen from each of the pathogens linked in a single molecule, as well as to genes coding for such chimeric molecules.

In this application, by the term "multimeric hybrid genes" we mean genes encoding antigenic regions of proteins from different pathogens and by the term "chimeric proteins" we mean immunogens containing antigenic regions from proteins from different pathogens.

BRIEF DESCRIPTION OF DRAWINGS

Figure 1 shows the nucleotide (SEQ ID No: 1) and amino acid (SEQ ID No: 2) sequence of a PCR-amplified PIV-3 F gene and F protein, respectively;

Figure 2 shows the restriction map of the PIV-3 F gene;

Figure 3 shows the nucleotide (SEQ ID No: 3) and amino acid (SEQ ID No: 4) sequences of the PIV-3 HN gene and HN protein, respectively;

Figure 4 shows the restriction map of the PIV-3 HN gene;

Figure 5 shows the nucleotide (SEQ ID No: 5) and amino acid (SEQ ID No: 6) sequences of the RSV F gene and RSV F protein, respectively;

Figure 6 shows the restriction map of the RSV F gene;

Figure 7 shows the nucleotide (SEQ ID No: 7) and amino acid (SEQ ID No: 8) sequences of the RSV G gene and
5 RSV G protein, respectively;

Figure 8 shows the restriction map of the RSV G gene;

Figure 9 shows the steps involved in the construction of an expression vector containing a
10 chimeric $F_{PIV-3} - F_{RSV}$ gene;

Figure 10 shows the steps involved in the construction of an expression vector containing a F_{PIV-3} gene lacking the 5'-untranslated sequence and transmembrane anchor and cytoplasmic tail coding regions;

15 Figure 11 shows the steps involved in the construction of an expression vector containing a chimeric $F_{PIV-3} - F_{RSV}$ gene containing a truncated PIV-3 F gene devoid of 5'-untranslated region linked to a truncated RSV F1 gene;

20 Figure 12 shows the steps involved in construction of a modified pAC 610 baculovirus expression vector containing a chimeric $F_{PIV-3} - F_{RSV}$ gene consisting of the PIV-3 F gene lacking both the 5'-untranslated sequence as well as transmembrane and cytoplasmic tail coding region
25 linked to the truncated RSV F1 gene;

Figure 13 shows immunoblots of cell lysates from Sf9 cells infected with recombinant baculoviruses;

Figure 14 shows the steps involved in constructing a baculovirus transfer vector (pD2);

30 Figure 15 shows the steps involved in construction of a chimeric $F_{RSV} - HN_{PIV-3}$ gene;

Figure 16 shows an SDS-PAGE gel and immunoblot of purified $F_{RSV} - HN_{PIV-3}$ chimeric protein;

35 Figure 17 illustrates mutagenesis of a PIV-3 F gene; and

Figure 18 shows the steps involved in the construction of a chimeric $F_{PIV-3} - G_{RSV}$ gene.

GENERAL DESCRIPTION OF INVENTION

5 In the present invention, a chimeric molecule protective against two different major childhood diseases is provided. The present invention specifically relates to the formulation of various recombinant Parainfluenza virus (PIV)/Respiratory syncytial virus (RSV) immunogens
10 to produce safe and efficacious vaccines capable of protecting infants and young children, as well as other susceptible individuals, against diseases caused by infection with both PIV and RSV. However, as described above, the present invention extends to the construction
15 of multimeric hybrid genes containing genes coding for protective antigens from many pathogens. Such vaccines may be administered in any desired manner, such as a readily-injectable vaccine, intranasally or orally.

In the present invention, the inventors have
20 specifically engineered several model PIV/RSV chimeric genes containing relevant sequences from selected genes coding for PIV-3 and RSV surface glycoproteins linked in tandem. All genes in the chimeric constructs described herein were obtained from recent clinical isolates of
25 PIV-3 and RSV. The chimeric gene constructs may include gene sequences from either PIV-3 F or HN genes linked in tandem to either RSV F or G genes in all possible relative orientations and combinations.

The chimeric gene constructs provided herein may
30 consist of either the entire gene sequences or gene segments coding for immunogenic and protective epitopes thereof. The natural nucleotide sequence of these genes may be modified by mutation while retaining antigenicity and such modifications may include the removal of
35 putative pre-transcriptional terminators to optimize their expression in eukaryotic cells. The genes were

designed to code for hybrid PIV-RSV surface glycoproteins linked in tandem in a single construct to produce gene products which elicit protective antibodies against both parainfluenza and respiratory syncytial viruses. Such

5 multimeric hybrid genes consist of a gene sequence coding for a human PIV-3 F or HN protein or an immunogenic epitope-containing fragment thereof linked to a gene sequence coding for a human RSV G or F protein or an immunogenic epitope-containing fragment thereof.

10 Specific gene constructs which may be employed include $F_{PIV-3} - F_{RSV}$, $F_{RSV} - HN_{PIV-3}$ and $F_{PIV-3} - G_{RSV}$ hybrid genes.

In addition, the present invention also extends to the construction of other multimeric genes, such as trimeric genes containing PIV and RSV genes or gene

15 segments, linked in all possible relative orientations. For example:

$F_{PIV} - HN_{PIV} - F$ or G_{RSV}

$F_{PIV} - F_{RSV} - G_{RSV}$

$HN_{PIV} - F_{RSV} - G_{RSV}$

20 The multimeric genes provided herein also may comprise at least one gene encoding at least one immunogenic and/or immunostimulating molecule.

The multimeric hybrid genes provided herein may be sub-cloned into appropriate vectors for expression in

25 cellular expression systems. Such cellular expression systems may include bacterial, mammalian, insect and fungal, such as yeast, cells.

The chimeric proteins provided herein also may be presented to the immune system by the use of a live

30 vector, including live viral vectors, such as recombinant poxviruses, adenoviruses, retroviruses, Semliki Forest viruses, and live bacterial vectors, such as Salmonella and mycobacteria (e.g. BCG).

Chimeric proteins, such as a PIV/RSV chimera,

35 present in either the supernatants or cell lysates of

transfected, transformed or infected cells then can be purified in any convenient manner.

To evaluate the immunogenicity and protective ability of the chimeric proteins, suitable experimental animals are immunized with either varying doses of the purified chimeric proteins, such as the PIV/RSV chimera, and/or live recombinant vectors as described above. Such chimeric proteins may be presented to the immune system by either the use of physiologically-acceptable vehicles, such as aluminum phosphate, or by the use of delivery systems, such as ISCOMS and liposomes. The chimeras also may be formulated to be capable of eliciting a mucosal response, for example, by conjugation or association with immunotargeting vehicles, such as the cholera toxin B subunit, or by incorporation into microparticles. The vaccines may further comprise means for delivering the multimeric protein specifically to cells of the immune system, such as toxin molecules or antibodies. To further enhance the immunoprotective ability of the chimeric proteins, they may be supplemented with other immunogenic and/or immunostimulating molecules. The chimeric PIV/RSV proteins specifically described herein may be formulated with an adjuvant, such as aluminum phosphate, to produce readily-injectable vaccines for protection against the diseases caused by both PIV-3 and RSV. The chimeric proteins also may be administered intranasally or orally. The chimeric proteins may be used in test kits for diagnosis of infection by PIV-3 and RSV.

The invention is not limited to the preparation of chimeric PIV-3 and RSV proteins, but is applicable to the production of chimeric immunogens composed of either the entire sequences or regions of the immunogenic proteins from at least two pathogens sequentially linked in a single molecule. Chimeric antigens also may be synthesized to contain the immunodominant epitopes of

several proteins from different pathogens. These chimeric antigens may be useful as vaccines or as diagnostic reagents.

SEQUENCE IDENTIFICATION

5 Several nucleotide and amino acid sequences are referred to in the disclosure of this application. The following table identifies the sequences and the location of the sequence:

10	<u>SEQ</u> <u>ID No.</u>	<u>Identification</u>	<u>Location</u>
	1	Nucleotide sequence for PCR-amplified PIV-3 F 15 gene	Fig. 1, Example 1
	2	Amino acid sequence for PCR-amplified PIV-F protein	Fig. 1, Example 1
20	3	Nucleotide sequence for PIV-3 HN gene	Fig. 3, Example 1
	4	Amino acid sequence for PIV-3 HN protein	Fig. 3, Example 1
25	5	Nucleotide sequence for RSV F gene	Fig. 5, Example 1
	6	Amino acid sequence for RSV F protein	Fig. 5, Example 1
30	7	Nucleotide sequence for RSV G gene	Fig. 7, Example 1
	8	Amino acid sequence for RSV G protein	Fig. 7, Example 1
35	9	BsrI - BamHI oligo- nucleotide cassette	Fig. 9, Example 2
40	10	BspHI - BamHI oligo- nucleotide cassette	Fig. 9, Example 2
	11	EcoRI - Ppu MI oligo- nucleotide cassette	Fig. 9, Example 2
45	12	BrsI - BamHI oligo- nucleotide cassette	Fig. 10, Example 3 -
50			

	13	EcoRI -Bsr BI oligo-nucleotide cassette	Fig. 10, Example 3
5	14	EcoRV - EcoRI oligo-nucleotide cassette	Fig. 11, Example 5
	15	EcoRV - BamHI oligo-nucleotide cassette	Fig. 14, Example 8
10	16	BspHI - BspHI oligo-nucleotide cassette	Fig. 15, Example 9
15	17	Nucleotide sequence for PIV-3 F gene	Example 15
	18	Mutagenic oligo-nucleotide #2721	Fig. 17, Example 15
20	19	Nucleotide sequence for part of oligo-nucleotide #2721	Example 15
25	20	Oligonucleotide probe	Example 15

DEPOSIT INFORMATION

Certain plasmid DNAs described and referred to herein have been deposited with the American Type Culture Collection (ATCC) located at Rockville, Maryland, USA, pursuant to the Budapest Treaty and prior to the filing of this application. The deposited purified plasmids will become available to the public upon grant of this U.S. patent application or upon publication of its corresponding European patent application, whichever first occurs. The invention described and claimed herein is not to be limited in scope by the plasmid DNAs of the constructs deposited, since the deposited embodiment is intended only as an illustration of the invention. The following purified plasmids were deposited at the ATCC with the noted accession numbers on December 17, 1992:

<u>Plasmid</u>	<u>Example No.</u>	<u>Accession No.</u>
pAC DR7	5	75387
pD2RF-HN	9	75388
pD2F-G	16	75389

Any equivalent plasmids that can be used to produce equivalent antigens as described in this application are within the scope of the invention.

EXAMPLES

5 The above disclosure generally describes the present invention. A more complete understanding can be obtained by reference to the following specific Examples. These Examples are described solely for purposes of illustration and are not intended to limit the scope of
10 the invention. Changes in form and substitution of equivalents are contemplated as circumstances may suggest or render expedient. Although specific terms have been employed herein, such terms are intended in a descriptive sense and not for purposes of limitations.

15 Methods for cloning and sequencing the PIV-3 and RSV genes as well as the procedures for sub-cloning the genes into appropriate vectors and expressing the gene constructs in mammalian and insect cells are not explicitly described in this disclosure but are well
20 within the scope of those skilled in the art.

Example 1:

This Example outlines the strategy used to clone and sequence the PIV-3 F, HN and RSV F, G genes (from a type A isolate). These genes were used in the construction of
25 the $F_{PIV-3} - F_{RSV}$, $F_{RSV} - HN_{PIV-3}$, and $F_{PIV-3} - G_{RSV}$ chimeric genes detailed in Examples 2 to 4, 9 and 15, respectively.

Two PIV-3 F gene clones initially were obtained by PCR amplification of cDNA derived from viral RNA extracted from a recent clinical isolate of PIV-3. Two
30 other PIV-3 F gene clones as well as the PIV-3 HN, RSV F and RSV G genes were cloned from a cDNA library prepared from mRNA isolated from MRC-5 cells infected with clinical isolates of either PIV-3 or RSV (type A isolate). The PIV-3 F (both PCR amplified and non-PCR
35 amplified), PIV-3 HN, RSV F and RSV G gene clones were sequenced by the dideoxynucleotide chain termination

procedure. Sequencing of both strands of the genes was performed by a combination of manual and automated sequencing.

The nucleotide (SEQ ID No: 1) and amino acid (SEQ ID No: 2) sequences of the PCR amplified PIV-3 F gene and F protein, respectively, are presented in Figure 1 and the restriction map of the gene is shown in Figure 2. Sequence analysis of the 1844 nucleotides of two PCR amplified PIV-3 F gene clones confirmed that the clones were identical. Comparison of the coding sequence of the PCR-amplified PIV-3 F gene clone with that of the published PIV-3 F gene sequence revealed a 2.6% divergence in the coding sequence between the two genes resulting in fourteen amino acid substitutions.

The nucleotide sequence of the non-PCR amplified PIV-3 F gene clone differed from the PCR amplified gene clone in the following manner: the non-PCR amplified clone had ten additional nucleotides (AGGACAAAAG) at the 5' untranslated region of the gene and differed at four positions, 8 (T in PCR-amplified gene to C in non-PCR amplified gene), 512 (C in PCR-amplified gene to T in non-PCR amplified gene), 518 (G in PCR-amplified gene to A in non-PCR amplified gene) and 1376 (A in PCR-amplified gene to G in non-PCR amplified gene). These changes resulted in three changes in the amino acid sequence of the F protein encoded by the non-PCR amplified PIV-3 F gene. Serine (position 110), glycine (position 112), and aspartic acid (position 398) in the primary amino acid sequence of the F protein encoded by the PCR amplified PIV-3 F gene was changed to phenylalanine (position 110), glutamic acid (position 112) and glycine (position 398), respectively, in the primary amino acid sequence of the F protein encoded by the PCR amplified clone.

Figure 3 shows the nucleotide (SEQ ID No: 3) and amino acid (SEQ ID No: 4) sequences of the PIV-3 HN gene and protein, respectively and the restriction map of the

gene is presented in Figure 4. Analysis of the 1833 nucleotide sequence from two HN clones confirmed that the sequences were identical. A 4.4% divergence in the coding sequence of the PIV-3 HN gene was noted when the sequence was compared to the published PIV-3 HN coding sequence. This divergence resulted in seventeen amino acid substitutions in the amino acid sequence of the protein encoded by the PIV-3 HN gene.

The nucleotide (SEQ ID No: 5) and amino acid (SEQ ID No: 6) sequences of the RSV F gene and RSV F protein, respectively, are shown in Figure 5 and the restriction map of the gene is shown in Figure 6. Analysis of the 1887 nucleotide sequence from two RSV F clones verified complete sequence homology between the two clones. Comparison of this nucleotide sequence with that reported for the RSV F gene revealed approximately 1.8% divergence in the coding sequence resulting in eleven amino acid substitutions.

The nucleotide (SEQ ID No: 7) and amino acid (SEQ ID No: 8) sequences of the RSV G gene and RSV G protein, respectively, are presented in Figure 7 while the restriction map of the gene is outlined in Figure 8. Comparison of the 920 nucleotide sequence of the G gene clone with the published G sequence (type A isolate) revealed a 4.2% divergence in the nucleotide sequence and a 6.7% divergence in the amino acid sequence of the gene product. This divergence resulted in twenty amino acid substitutions.

The full-length PIV-3 F (non-PCR amplified) , PIV-3 HN, RSV F and RSV G genes were cloned into λ gt11 and subcloned into the multiple cloning site of a Bluescript M13-SK vector, either by blunt end ligation or using appropriate linkers. The PCR-amplified PIV-3 F gene was directly cloned into the Bluescript vector. The cloning vectors containing the PIV-3 F-PCR amplified, PIV-3 F non-PCR amplified, PIV-3 HN, RSV F and RSV G genes were

named pPI3F, pPI3Fc, pPIVHN, pRSVF and pRSVG, respectively.

Example 2:

This Example illustrates the construction of a
5 Bluescript-based expression vector (pMCR20) containing
the chimeric $F_{PIV-3} - F_{RSV}$ gene. This chimeric gene
construct contains the 5' untranslated region of the PIV-
3 F gene but lacks the hydrophobic anchor and cytoplasmic
tail coding regions of both the PIV-3 and RSV F genes.
10 The steps involved in the construction of this plasmid
are summarized in Figure 9.

To prepare the PIV-3 portion of the chimeric gene
(Figure 9, step 1), the full length PIV-3 gene lacking
the transmembrane region and cytoplasmic tail coding
15 regions was retrieved from plasmid pPI3F by cutting the
polylinker with BamHI, blunt-ending the linearized
plasmid with Klenow polymerase and cutting the gene with
BsrI. A BsrI-BamHI oligonucleotide cassette (SEQ ID No:
9) containing a PpuMI site and three successive
20 translational stop codons were ligated to the truncated
1.6 Kb [BamHI]-BsrI PIV-3 F gene fragment and cloned into
the EcoRV-BamHI sites of a Bluescript M13-SK expression
vector containing the human methallothionin promoter and
the poly A and IVS sequences of the SV40 genome
25 (designated pMCR20), to generate plasmid pME1.

To engineer the RSV F gene component of the chimeric
construct (Figure 9, step 2), the RSV F gene lacking the
transmembrane region and cytoplasmic tail coding regions
was retrieved from plasmid pRSVF by cutting the
30 polylinker with EcoRI and the gene with BspHI. A
synthetic BspHI-BamHI oligonucleotide cassette (SEQ ID
No: 10) containing three successive translational stop
codons was ligated to the 1.6 Kb truncated RSV F gene and
cloned into the EcoRI-BamHI sites of the Bluescript based
35 expression vector, pMCR20 to produce plasmid pES13A.
Plasmid pES13A then was cut with EcoRI and PpuMI to

remove the leader and F2 coding sequences from the truncated RSV F gene. The leader sequence was reconstructed using an EcoRI-PpuMI oligocassette (SEQ ID No: 11) and ligated to the RSV F1 gene segment to generate plasmid pES23A.

To prepare the chimeric F_{PIV-3} - F_{RSV} gene (Figure 9, step 3) containing the 5' untranslated region of the PIV-3 F gene linked to the truncated RSV F1 gene fragment, plasmid pME1 (containing the 1.6 Kb truncated PIV-3 F gene) first was cut with PpuMI and BamHI. The PpuMI-BamHI restricted pME1 vector was dephosphorylated with intestinal alkaline phosphatase. The 1.1 Kb RSV F1 gene fragment was retrieved from plasmid pES23A by cutting the plasmid with PpuMI and BamHI. The 1.1 Kb PpuMI-BamHI RSV F1 gene fragment was cloned into the PpuMI-BamHI sites of the dephosphorylated pME1 vector to generate plasmid pES29A. This chimeric gene construct contains the 5' untranslated region of the PIV-3 F gene but lacks the nucleotide sequences coding for the hydrophobic anchor domains and cytoplasmic tails of both the PIV-3 and RSV F proteins.

Example 3:

This Example illustrates the construction of a Bluescript-based expression vector containing the PIV-3 F gene lacking both the 5' untranslated and transmembrane anchor and cytoplasmic tail coding regions. The steps involved in constructing this plasmid are outlined in Figure 10.

Plasmid pPI3F containing the full length PIV-3 F gene was cut with BamHI, blunt ended with Klenow polymerase and then cut with BsrI to remove the transmembrane and cytoplasmic tail coding regions. The Bluescript-based expression vector, pMCR20, was cut with SmaI and BamHI. A synthetic BsrI-BamHI oligonucleotide cassette (SEQ ID No: 12) containing a translational stop codon was ligated with the 1.6 Kb blunt ended-BsrI PIV-3

F gene fragment to the SmaI-BamHI restricted pMCR20 vector to produce plasmid pMpFB. The PIV-3 F gene of this construct lacked the DNA fragment coding for the transmembrane and cytoplasmic anchor domains but
5 contained the 5' untranslated region. To engineer a plasmid containing the PIV-3 F gene devoid of both the 5' untranslated region and the DNA fragment coding for the hydrophobic anchor domain, plasmid pMpFB was cut with EcoRI and BstBI. An EcoRI-BstBI oligocassette (SEQ ID
10 No: 13) containing the sequences to reconstruct the signal peptide and coding sequences removed by the EcoRI-BstBI cut was ligated to the EcoRI-BstBI restricted pMpFB vector to produce plasmid pMpFA.

Example 4:

15 This Example illustrates the construction of the chimeric F_{PIV-3} - F_{RSV} gene composed of the truncated PIV-3 F gene devoid of the 5' untranslated region linked to the truncated RSV F1 gene. The steps involved in constructing this plasmid are summarized in Figure 11.

20 To prepare this chimeric gene construct, plasmid pES29A (Example 2) was cut with BstBI and BamHI to release the 2.5 Kb BstBI-BamHI PIV-3 F-RSV F1 chimeric gene fragment. This BstBI-BamHI fragment was isolated from a low melting point agarose gel and cloned into the
25 BstBI-BamHI sites of the dephosphorylated vector pMpFA to produce plasmid pES60A. This construct contained the PIV-3 F gene lacking both the 5' untranslated region and the hydrophobic anchor and cytoplasmic tail coding sequences linked to the F1 coding region of the truncated
30 RSV F gene. This chimeric gene was subsequently subcloned into the baculovirus transfer vector (see Example 5).

Example 5:

This Example illustrates the construction of the
35 modified pAC 610 baculovirus transfer vector containing the native polyhedrin promoter and the chimeric F_{PIV-3} - F_{RSV}

gene consisting of the PIV-3 F gene lacking both the 5' untranslated sequence and the nucleotide sequence coding for the hydrophobic anchor domain and cytoplasmic tail linked to the truncated RSV F1 gene. Construction of this plasmid is illustrated in Figure 12. —

The pAC 610 baculovirus expression vector was modified to contain the native polyhedrin promoter in the following manner. Vector pAC 610 was cut with EcoRV and BamHI. The 9.4 Kb baculovirus transfer vector lacking the EcoRV-BamHI DNA sequence was isolated from a low melting point agarose gel and treated with intestinal alkaline phosphatase. In a 3-way ligation, an EcoRV-EcoRI oligonucleotide cassette (SEQ ID No: 14) containing the nucleotides required to restore the native polyhedrin promoter was ligated with the 1.6 Kb EcoRI-BamHI truncated RSV F gene fragment isolated from construct pES13A (Example 2, step 2) and the EcoRV-BamHI restricted pAC 610 phosphatased vector to generate plasmid pES47A. To prepare the pAC 610 based expression vector containing the chimeric F_{PIV-3} - F_{RSV} gene, plasmid pES47A was first cut with EcoRI and BamHI to remove the 1.6 Kb truncated RSV F gene insert. The 2.8 Kb F_{PIV-3} - F_{RSV} chimeric gene was retrieved by cutting plasmid pES60A (Example 4) with EcoRI and BamHI. The 2.8 Kb EcoRI-BamHI chimeric gene was ligated to the EcoRI-BamHI restricted pES47A vector to generate plasmid pAC DR7 (ATCC 75387).

Example 6

This Example outlines the preparation of plaque-purified recombinant baculoviruses containing the chimeric F_{PIV-3} - F_{RSV} gene.

Spodoptera frugiperda (Sf9) cells were co-transfected with 1.0 μ g wild-type AcMNPV DNA and 2.5 μ g of F_{PIV-3} - F_{RSV} plasmid DNA (plasmid pAC DR7 - Example 5). Putative recombinant baculoviruses (purified once by serial dilution) containing the F_{PIV-3} - F_{RSV} chimeric gene were identified by dot-blot hybridization. Lysates of

insect cells infected with the putative recombinant baculoviruses were probed with the ^{32}P -labelled $\text{F}_{\text{PIV-3}}\text{-F}_{\text{RSV}}$ chimeric gene insert. Recombinant baculoviruses were plaque-purified twice before being used for expression studies. All procedures were carried out according to the protocols outlined by M.D. Summers and G.E. Smith in "A Manual of Methods for Baculovirus Vectors and Insect Cell Culture Procedures", Texas Agricultural Experiment Station, Bulletin 1555, 1987.

10 Example 7:

This Example illustrates the presence of the chimeric $\text{F}_{\text{PIV-3}}\text{-F}_{\text{RSV}}$ protein in supernatants and cell lysates of infected Sf9 cells.

Insect cells were infected with the plaque-purified recombinant baculoviruses prepared as described in Example 6 at a m.o.i. of 8. Concentrated supernatants from cells infected with the recombinant viruses were positive in a PIV-3 F specific ELISA. In addition, when lysates from ^{35}S -methioninelabelled infected cells were subjected to SDS-polyacrylamide gel electrophoresis and gels were analyzed by autoradiography, a strong band with apparent molecular weight of approximately 90 kDa was present in lysates of cells infected with the recombinant viruses but was absent in the lysates from wild-type infected cells. The presence of the chimeric $\text{F}_{\text{PIV-3}}\text{-F}_{\text{RSV}}$ protein in the lysates of cells infected with the recombinant baculoviruses was confirmed further by Western blot analysis using monospecific anti-PIV-3 F and anti-RSV F antisera and/or monoclonal antibodies (Mabs). Lysates from cells infected with the recombinant baculoviruses reacted with both anti-PIV-3 and anti-RSV antisera in immunoblots. As shown in the immunoblot of Figure 13, lysates from cells infected with either the RSV F or $\text{F}_{\text{PIV-3}}\text{-F}_{\text{RSV}}$ recombinant baculoviruses reacted positively with the anti-F RSV Mab. As expected, lysates from cells infected with wild type virus did not react

with this Mab. In addition, only lysates from cells infected with the chimeric $F_{PIV-3} - F_{RSV}$ recombinant viruses reacted with the anti-PIV-3 F_1 antiserum.

Example 8

5 This Example illustrates modification of the baculovirus transfer vector pVL1392 (obtained from Invitrogen), wherein the polyhedrin ATG start codon was converted to ATT and the sequence CCG was present downstream of the polyhedrin gene at positions +4,5,6.
10 Insertion of a structural gene several base pairs downstream from the ATT codon is known to enhance translation. The steps involved in constructing this modified baculovirus transfer vector are outlined in Figure 14.

15 The baculovirus expression vector pVL1392 was cut with EcoRV and BamHI. The 9.5 kb restricted pVL1392 vector was ligated to an EcoRV-BamHI oligonucleotide cassette (SEQ ID No: 15) to produce the pD2 vector.

Example 9:

20 This Example illustrates the construction of the pD2 baculovirus expression vector containing the chimeric $F_{RSV} - HN_{PIV-3}$ gene consisting of the truncated RSV F and PIV-3 HN genes linked in tandem. The steps involved in constructing this plasmid are summarized in Figure 15.

25 To engineer the $F_{RSV} - HN_{PIV-3}$ gene, the RSV F gene lacking the nucleotide sequence coding for the transmembrane domain and cytoplasmic tail of the RSV F glycoprotein was retrieved from plasmid pRSVF (Example 1) by cutting the polylinker with EcoRI and the gene with
30 BspHI. The PIV-3 HN gene devoid of the DNA fragment coding for the hydrophobic anchor domain was retrieved from plasmid pPIVHN (Example 1) by cutting the gene with BspHI and the polylinker with BamHI. The 1.6 Kb EcoRI-BspHI RSV F gene fragment and the 1.7 Kb BspHI-BamHI PIV-
35 3 HN gene fragment were isolated from low melting point-agarose gels. For cloning purposes, the two BspHI sites

in the Bluescript based mammalian cell expression vector, pMCR20, were mutated. Mutations were introduced in the BspHI sites of the pMCR20 by cutting the expression vector with BspHI, treating both the BspHI restricted
5 vector and the 1.1 Kb fragment released by the BspHI cut with Klenow polymerase and ligating the blunt-ended 1.1 Kb fragment to the blunt-ended Bluescript-based expression vector to generate plasmid pM'. Since
10 insertion of the 1.1 Kb blunt-end fragment in the mammalian cell expression vector in the improper orientation would alter the Amp^r gene of the Bluescript-based expression vector, only colonies of HB101 cells transformed with the pM' plasmid DNA with the 1.1 Kb blunt-ended fragment in the proper orientation could
15 survive in the presence of ampicillin. Plasmid DNA was purified from ampicillin-resistant colonies of HB101 cells transformed with plasmid pM' by equilibrium centrifugation in cesium chloride-ethidium bromide gradients. The 1.6 Kb EcoRI-BspHI RSV F and 1.7 Kb
20 BspHI-BamHI PIV-3 HN gene fragments were directly cloned into the EcoRI-BamHI sites of vector pM' in a 3-way ligation to generate plasmid pM' RF-HN.

To restore specific coding sequences of the RSV F and PIV-3 HN genes removed by the BspHI cut, a BspHI-
25 BspHI oligonucleotide cassette (SEQ ID No: 16) containing the pertinent RSV F and PIV-3 HN gene sequences was ligated via the BspHI site to the BspHI-restricted plasmid pM' RF-HN to produce plasmid pM RF-HN. Clones containing the BspHI-BspHI oligonucleotide cassette in
30 the proper orientation were identified by sequence analysis of the oligonucleotide linker and its flanking regions.

To clone the chimeric F_{RSV}-HN_{PIV-3} gene into the baculovirus expression vector pD2 (Example 8), the F_{RSV}-
35 HN_{PIV-3} truncated gene first was retrieved from plasmid pM RF-HN by cutting the plasmid with EcoRI. The 3.3 Kb F_{RSV}-

HN_{PIV-3} gene then was cloned into the EcoRI site of the baculovirus transfer vector plasmid pD2 to generate plasmid pD2 RF-HN (ATCC 75388). Proper orientation of the 3.3 Kb EcoRI F_{RSV}-HN_{PIV-3} chimeric gene insert in
5 plasmid pD2 RF-HN was confirmed by sequence analysis.

Example 10:

This Example outlines the preparation of plaque-purified recombinant baculoviruses containing the chimeric F_{RSV}-HN_{PIV-3} gene.

10 Spodoptera frugiperda (Sf9) cells were co-transfected with 1 µg wild-type AcNPV DNA and 2 µg of F_{RSV}-HN_{PIV-3} plasmid DNA (plasmid pD2 RF-HN-Example 9). Putative recombinant baculoviruses (purified once by serial dilution) containing the F_{RSV}-HN_{PIV-3} chimeric gene
15 were identified by dot-blot hybridization. Lysates of insect cells infected with the putative recombinant baculoviruses were probed with the ³²P-labelled RSV F or PTV-3 HN gene oligonucleotide probes. Recombinant baculoviruses were plaque-purified three times before
20 being used for expression studies. All procedures were carried out according to the protocols outlined by Summers and Smith (Example 6).

Example 11:

This Example illustrates the presence of the
25 chimeric F_{RSV}-HN_{PIV-3} protein in supernatants of infected Sf9 and High 5 cells.

Insect cells (Sf9 and High 5), maintained in serum free medium EX401, were infected with the plaque purified recombinant baculoviruses of Example 10 at a m.o.i. of 5
30 to 10 pfu/cell. Supernatants from cells infected with the recombinant baculoviruses tested positive for expressed protein in both the RSV-F and PIV-3 HN specific ELISAS. In addition, supernatants from infected cells reacted positively with both an anti-F RSV monoclonal
35 antibody and anti-HN peptide antisera on immunoblots. A distinct band of approximately 105 kDa was present in the

immunoblots. These results confirm the secretion of the chimeric $F_{RSV}-HN_{PIV-3}$ protein into the supernatant of Sf9 and High 5 cells infected with the recombinant baculoviruses.

5 Example 12:

This Example illustrates the purification of the chimeric $F_{RSV}-HN_{PIV-3}$ protein from the supernatants of infected High 5 cells.

High 5 cells, maintained in serum free medium, were
10 infected with the plaque purified recombinant baculoviruses of Example 10 at a m.o.i of 5 pfu/cell. The supernatant from virus infected cells was harvested 2 days post-infection. The soluble $F_{RSV}-HN_{PIV-3}$ chimeric protein was purified from the supernatants of infected
15 cells by immunoaffinity chromatography using an anti-HN PIV-3 monoclonal antibody. The anti-HN monoclonal antibody was coupled to CNBr-activated Sepharose 4B by conventional techniques. The immunoaffinity column was washed with 10 bed volumes of washing buffer (10mM Tris-
20 HCl pH 7.5, 150 mM NaCl, 0.02% v/v Triton-X 100) prior to use. After sample loading, the column was washed with 10 bed volumes of washing buffer followed by 3 bed volumes of high salt buffer (10mM Tris-HCl pH 7.5, 500mM NaCl, 0.02% v/v Triton-X 100). The chimeric $F_{RSV}-HN_{PIV-3}$ protein
25 was eluted from the immunoaffinity column with 100 mM glycine, pH 2.5, in the presence of 0.02% Triton X-100. Eluted protein was neutralized immediately with 1M Tris-HCl, pH 10.7.

Polyacrylamide gel electrophoretic analysis (Fig.
30 16, panel A) of the immunoaffinity-purified $F_{RSV}-HN_{PIV-3}$ protein revealed the presence of one major protein band with an apparent molecular weight of 105 kDa. The purified protein reacted with both an anti-RSV F monoclonal antibody and anti-HN peptide antisera on
35 immunoblots (Fig. 16, panel B, lanes 1 and 2, respectively).

Example 13:

This Example illustrates the immunogenicity of the $F_{RSV}-HN_{PIV-3}$ protein in guinea pigs.

Groups of four guinea pigs were injected
5 intramuscularly with either 1.0 or 10.0 μ g of the
chimeric $F_{RSV}-HN_{PIV-3}$ protein purified as described in
Example 12 and adjuvanted with aluminum phosphate.
Groups of control animals were immunized with either
placebo, or live PIV-3 or RSV (administered
10 intranasally). Guinea pigs were bled 2 and 4 weeks after
the primary injection and boosted at 4 weeks with an
equivalent dose of the antigen formulation. Serum
samples also were taken 2 and 4 weeks after the booster
dose. To assess the ability of the chimeric protein to
15 elicit PIV-3 and RSV-specific antibody responses, sera
samples were analyzed for the presence of PIV-3 specific
hemagglutination inhibiting and neutralizing antibodies
as well as RSV neutralizing antibodies. As summarized in
Table 1 below (the Tables appear at the end of the
20 disclosure), the sera of animals immunized with two 10 μ g
doses of the chimeric protein had titres of PIV-3
specific hemagglutination inhibition (HAI) and PIV-3/RSV
neutralizing antibodies at the 6 and 8 week time points
which were equivalent to the levels obtained following
25 intranasal inoculation with either live PIV-3 or RSV. In
addition, animals immunized with only two 1 μ g doses of
the chimeric protein elicited strong PIV-3 and RSV
specific neutralizing antibodies. These results
confirmed the immunogenicity of both the RSV and PIV-3
30 components of the chimeric protein and provided
confirmatory evidence that a single recombinant immunogen
can elicit neutralizing antibodies against both RSV and
PIV-3.

Example 14:

This Example illustrates the immunogenicity and protective ability of the $F_{RSV}-HN_{PIV-3}$ protein in cotton rats.

Groups of eight cotton rats were injected intramuscularly with either 1.0 or 10.0 μ g of the chimeric $F_{RSV}-HN_{PIV-3}$ protein (prepared as described in Example 12) adjuvanted with aluminum phosphate. Groups of control animals were immunized with either placebo (PBS + aluminum phosphate) or live PIV-3 or RSV (administered intranasally). Cotton rats were bled 4 weeks after the primary injection and boosted at 4 weeks with an equivalent dose of the antigen formulation. Serum samples were also taken 1 week after the booster dose. As shown in Table 2 below, data from the 4-week bleed demonstrated that both a 1 and 10 μ g dose of the chimeric protein was capable of inducing a strong primary response. Reciprocal mean \log_2 PIV-3 specific HAI and PIV-3/RSV neutralizing titers were equivalent to the titres obtained with live PIV-3 and RSV. Thus, a single inoculation of the chimeric protein was sufficient to elicit neutralizing antibodies against both PIV-3 and RSV. Strong neutralizing PIV-3 and RSV titres also were observed following the booster dose (5 week bleed). These results provide additional evidence that both the RSV and PIV-3 components of the chimeric protein are highly immunogenic.

To assess the ability of the chimeric immunogen to simultaneously protect animals against both RSV and PIV-3, four cotton rats from each group were challenged intranasally with 100 TCID₅₀ units of either PIV-3 or RSV. Animals were killed 4 days after virus challenge. Virus titers were determined in lung homogenates. As shown in Table 3 below, animals immunized with either 1 or 10 μ g of the chimeric $F_{RSV}-HN_{PIV-3}$ protein were completely protected against challenge with either PIV-3 or RSV. These results provide evidence that the chimeric protein

is not only highly immunogenic but can also simultaneously protect cotton rats against disease caused by both PIV-3 and RSV infection.

Example 15:

5 This Example illustrates the construction of a Bluescript M13-SK vector containing the chimeric $F_{PIV-3}-G_{RSV}$ gene. This chimeric gene construct contains the 5' untranslated region of a mutated PIV-3 F gene but lacks the nucleotide sequence coding for the hydrophobic anchor
10 and cytoplasmic tail domains of both a mutated PIV-3 F and the native RSV G genes. The steps involved in constructing this plasmid are outlined in Figures 17 and 18.

 The first step (Fig. 17) involved in preparing the
15 PIV-3 F component of the chimeric $F_{PIV-3}-G_{RSV}$ gene construct was to eliminate the putative pre-termination sites within the 18 nucleotide long sequence 5' CAAGAAAAAGGAATAAAA 3' (SEQ ID No: 17) located between positions 857 and 874 of the non PCR-amplified PIV-3 F
20 gene and positions 847 and 864 of the PCR-amplified PIV-3 F gene (see Figure 1). To this end, the PIV-F cDNA of the non-PCR amplified PIV-3 F gene was cut at the BsaAI and EcoRI sites. The BsaAI-EcoRI PIV F gene fragment was cloned into the EcoRI site of a Bluescript M13-SK vector
25 using an EcoRI-BsaAI linker. The 857-874 target region of the PIV-3 F gene (non-PCR amplified) then was mutated by oligonucleotide-mediated mutagenesis using the method of Morinaga et al. [1984, Biotechnology 2: 636-639]. Plasmid pPI3Fc (Example 1) was cut with ScaI in the Amp^r
30 gene and dephosphorylated with alkaline phosphatase (plasmid #1). A second sample of plasmid pPI3Fc was cut with BstEII and NsiI to produce a 3.9 Kb restricted plasmid, lacking the 0.9 Kb BstEII-NsiI fragment of the PIV-3 F gene (plasmid #2). A mutagenic 78-mer synthetic
35 oligonucleotide (#2721 shown in Fig. 17-SEQ ID No: 18)) containing the sequence 5' CAGGAGAAGGGTATCAAG 3' (SEQ ID

No: 19) was synthesized to specifically mutate the 857-874 DNA segment without changing the F protein sequence. This oligonucleotide was added to plasmid DNAs #1 and #2, denatured at 100°C for 3 min. and renatured by gradual
5 cooling. The mixture then was incubated in the presence of DNA polymerase, dNTPs and T4 ligase and transformed into HB101 cells. Bacteria containing the 1.8 Kb mutated PIV-3 F gene were isolated on YT agar plates containing 100 µg/ml ampicillin. Hybridization with the
10 oligonucleotide probe 5' AGGAGAAGGGTATCAAG 3' (SEQ ID No: 20) was used to confirm the presence of the mutated PIV-3 F gene. The mutated gene sequence was confirmed by DNA sequencing. The plasmid containing the mutated PIV-3 gene was designated pPI3Fm.

15 The second step (Fig. 18) in the engineering of the chimeric gene construct involved constructing a Bluescript based vector to contain the truncated PIV-3 Fm gene lacking the nucleotide sequence coding for the transmembrane anchor domain and cytoplasmic tail of the
20 PIV-3 F protein linked in tandem with the RSV G gene lacking both the 5' leader sequence and the nucleotide sequence coding for the transmembrane anchor domain and cytoplasmic tail of the G glycoprotein.

To prepare this chimeric gene, the orientation of
25 the mutated PIV-F gene in plasmid pPI3Fm first was reversed by EcoRI digestion and religation to generate plasmid pPI3Fmr. To prepare the PIV-3 F gene component of the chimeric gene, plasmid pPI3Fmr was cut with NotI and BsrI to release the 1.7 Kb truncated PIV-3 F gene.
30 To prepare the RSV G component, the 0.95 Kb RSV-G gene lacking both the 5' leader sequence and the DNA segment encoding the G protein anchor domain and cytoplasmic tail was released from plasmid pRSVG (Example 1) by cutting the polylinker with EcoRI and the gene with BamHI. The
35 0.95 Kb EcoRI-BamHI RSV G gene fragment was subcloned into the EcoRI-BamHI sites of a restricted Bluescript

vector, pM13-SK, to produce plasmid pRSVGt. The 0.95 Kb EcoRI-BamHI G gene fragment and the 1.5 Kb NotI-BsrI truncated PIV-3 F gene were linked via a BsrI-BamHI oligonucleotide cassette (SEQ ID No: 9) restoring the F and G gene coding sequences and cloned into the pRSVGt vector restricted with BamHI and NotI in a 3-way ligation. The plasmid thus generated was designated pFG.

Example 16:

This Example outlines the construction of the pD2 baculovirus transfer vector (described in Example 8) containing the chimeric F_{PIV-3} - G_{RSV} gene consisting of a mutated PIV-3 F gene lacking the hydrophobic anchor and cytoplasmic coding regions linked to the RSV G gene lacking both the 5' leader sequence and the nucleotide sequences encoding the transmembrane anchor domain and cytoplasmic tail of the G protein.

To prepare this construct, plasmid pFG (Example 15) was cut with EcoRI to release the 2.6 Kb F_{PIV-3} - G_{RSV} chimeric gene. The 2.6 Kb EcoRI restricted chimeric gene fragment then was sub-cloned into the EcoRI site of the dephosphorylated pD2 vector to generate the 12.1 Kb plasmid pD2F-G (ATCC 75389).

Example 17:

This Example outlines the preparation of plaque-purified recombinant baculoviruses containing the chimeric F_{PIV-3} - G_{RSV} gene.

Spodoptera frugiperda (Sf9) cells were co-transfected with 2 ug of pD2F-G plasmid DNA (Example 16) and 1 ug of linear wild-type AcNPV DNA (obtained from Invitrogen). Recombinant baculoviruses containing the F_{PIV-3} - G_{RSV} gene were plaque-purified twice according to the procedure outlined in Example 10.

Example 18:

This Example illustrates the presence of the chimeric F_{PIV-3} - G_{RSV} protein in the supernatant of Sf9 and High 5 cells infected with the recombinant baculoviruses.

Sf9 and High 5 cells were infected with recombinant baculoviruses containing the F_{PIV-3} - G_{RSV} gene (Example 16) at a m.o.i. of 5 to 10 pfu/cell. The supernatant of cells infected with the recombinant viruses tested
5 positive for expressed protein in the PIV-3_F specific ELISA. Supernatants of infected cells reacted with both anti-F PIV-3 and anti-G RSV monoclonal antibodies in immunoblots. These results confirm the presence of the chimeric F_{PIV-3} - G_{RSV} protein in the supernatants of infected
10 Sf9 and High 5 cells.

Example 19:

This Example outlines the preparation of recombinant vaccinia viruses expressing the F_{PIV-3} - F_{RSV} and F_{RSV} - HN_{PIV-3} genes.

15 Vaccinia virus recombinant viruses expressing the F_{PIV-3} - F_{RSV} (designated vP1192) and F_{RSV} - HN_{PIV-3} (designated vP1195) genes were produced at Virogenetics Corporation (Troy, NY) (an entity related to assignee hereof) using the COPAK host-range selection system. Insertion
20 plasmids used in the COPAK host-range selection system contained the vaccinia K1L host-range gene [Perkus et al., (1990) Virology 179:276-286] and the modified vaccinia H6 promoter [Perkus et al. (1989), J. Virology 63:3829-3836]. In these insertion plasmids, the K1L
25 gene, H6 promoter and polylinker region are situated between Copenhagen strain vaccinia flanking arms replacing the ATI region [open reading frames (ORFs) A25L, A26L; Goebel et al., (1990), Virology 179: 247-266; 517-563]. COPAK insertion plasmids are designed for use
30 in in vivo recombination using the rescue virus NYVAC (vP866) (Tartaglia et al., (1992) Virology 188: 217-232). Selection of recombinant viruses was done on rabbit kidney cells.

Recombinant viruses, vP1192 and vP1195 were
35 generated using insertion plasmids pES229A-6 and PSD.RN, respectively. To prepare plasmid pES229A-6 containing

the $F_{PIV.3}-F_{RSV}$ gene, the COPAK-H6 insertion plasmid pSD555 was cut with SmaI and dephosphorylated with intestinal alkaline phosphatase. The 2.6 Kb $F_{PIV.3}-F_{RSV}$ gene was retrieved from plasmid pES60A (Example 4) by cutting the
5 plasmid with EcoRI and BamHI. The 2.6 Kb EcoRI-BamHI $F_{PIV.3}-F_{RSV}$ gene was blunt ended with Klenow polymerase, isolated from a low melting point agarose gel and cloned into the SmaI site of the COPAK-H6 insertion plasmid pSD555 to generate plasmid pES229A-6. This positioned
10 the $F_{PIV.3}-F_{RSV}$ ORF such that the 5' end is nearest the H6 promoter.

To prepare plasmid PSD.RN, the pSD555 vector first was cut with SmaI and BamHI. Plasmid pM RF-HN (Example 9) containing the truncated $F_{RSV}-HN_{PIV.3}$ gene was cut with
15 ClaI, blunt ended with Klenow polymerase and then cut with BamHI. The 3.3 Kb $F_{RSV}-HN_{PIV.3}$ gene was cloned into the SmaI-BamHI sites of the pSD555 vector to generate plasmid PSD.RN. This positioned the $F_{RSV}-HN_{PIV.3}$ ORF such that the H6 5' end is nearest the H6 promoter.

20 Plasmids pES229A-6 and PSD.RN were used in in vitro recombination experiments in vero cells with NYVAC (vP866) as the rescuing virus. Recombinant progeny virus was selected on rabbit kidney (RK)-13 cells (ATCC #CCL37). Several plaques were passaged two times
25 on RK-13 cells. Virus containing the chimeric genes were confirmed by standard in situ plaque hybridization [Piccini et al. (1987), Methods in Enzymology, 153:545-563] using radiolabeled probes specific for the PIV and RSV inserted DNA sequences. Plaque purified virus
30 containing the $F_{PIV.3}-F_{RSV}$ and $F_{RSV}-HN_{PIV.3}$ chimeric genes were designated vP1192 and vP1195, respectively.

Radioimmunoprecipitation was done to confirm the expression of the chimeric genes in vP1192 and vP1195 infected cells. These assays were performed with lysates
35 prepared from infected Vero cells [according to the procedure of Taylor et al., (1990) J. Virology 64, 1441-

1450] using guinea pig monospecific PIV-3 anti-HN and anti-F antiserum and rabbit anti-RSV F antiserum. Both the anti-PIV F and anti-RSV F antisera precipitated a protein with an apparent molecular weight of approximately 90 kDa from vP1192 infected Vero cells. Both anti-RSV F and guinea pig anti-PIV HN antisera precipitated a protein with an apparent molecular weight of approximately 100 kDa from vP1195 infected cells. These results confirmed the production of the $F_{PIV-3}-F_{RSV}$ and $F_{RSV}-HN_{PIV-3}$ chimeric proteins in Vero cells infected with the recombinant poxviruses.

SUMMARY OF DISCLOSURE

In summary of the disclosure, the present invention provides multimeric hybrid genes which produce chimeric proteins capable of eliciting protection against infection by a plurality of pathogens, particularly PIV and RSV. Modifications are possible within the scope of this invention.

Table 1 Secondary antibody response of guinea pigs immunized with the chimeric $F_{RSV-HN_{PIV-3}}$ protein

Antigen Formulation	Dose (ug)	HA1 Titre ^a (log ₂ ± s.e.)		Neutralization Titre ^b (log ₂ ± s.e.)			
		PIV-3		PIV-3		RSV	
		6 wk Bleed	8 wk Bleed	6 wk Bleed	8 wk Bleed	6 wk Bleed	8 wk Bleed
Buffer	-	<1.0 ± 0.0	<1.0 ± 0.0	<1.0 ± 0.0	<1.0 ± 0.0	<1.0 ± 0.0	<1.0 ± 0.0
$F_{RSV-HN_{PIV-3}}$	10.0	9.1 ± 0.3	9.1 ± 0.3	7.1 ± 0.3	7.1 ± 0.5	5.5 ± 0.9	4.5 ± 1.2
	1.0	7.0 ± 2.0	7.3 ± 2.2	5.0 ± 1.5	4.5 ± 1.4	4.5 ± 0.5	3.0 ± 1.0
Live PIV-3		8.6 ± 0.7	7.3 ± 0.6	7.0 ± 0.4	7.3 ± 0.6	N/A	N/A
Live RSV		N/A ^c	N/A	N/A	N/A	5.5 ± 1.5	5.0 ± 1.0

^a Reciprocal mean log₂ serum dilution which inhibits erythrocyte agglutination by 4 hemagglutinating units of PIV-3

^b Reciprocal mean log₂ serum dilution which blocks hemadsorption of 100 TCID₅₀ units of PIV-3 or RSV

^c N/A - not applicable

Table 2: Serum antibody response of cotton rats immunized with the chimeric $r_{ASV-HN_{MV3}}$ protein^a

Antigen Formulation	Dose (μ g)	HA1 Titre ^b ($\log_2 \pm$ s.d.)		Neutralization Titre ^c ($\log_2 \pm$ s.d.)		
		PIV-3		PIV-3		
		4 wk Bleed	5 wk Bleed	4 wk Bleed	5 wk Bleed	5 wk Bleed
Buffer	-	2.8 \pm 0.5	<3.0 \pm 0.0	<1.0 \pm 1.0	<1.0 \pm 0.0	0.8 \pm 0.7
$r_{ASV-HN_{MV3}}$	10.0	9.5 \pm 1.3	10.5 \pm 0.6	>9.0 \pm 0.0	>9.0 \pm 0.0	5.8 \pm 0.9
	1.0	9.3 \pm 1.0	10.3 \pm 0.5	>9.0 \pm 0.0	>9.0 \pm 0.0	5.8 \pm 1.2
Live PIV-3		7.0 \pm 0.0	8.5 \pm 0.7	>9.0 \pm 0.0	9.2 \pm 0.7	N/A
Live RSV		N/A ^d	N/A	N/A	N/A	5.5 \pm 0.6

^a Each value represents the mean titre of antisera from 8 animals.^b Reciprocal mean \log_2 serum dilution which inhibits erythrocyte agglutination by 4 hemagglutinating units of PIV-3^c Reciprocal mean \log_2 serum dilution which blocks hemadsorption of 100 TCID₅₀ units of PIV-3 or RSV^d N/A - not applicable

Table 3. Response of immunized cotton rats to PIV/RSV challenge^a

Antigen Formulation	Dose (ug)	Mean virus lung titre log ₁₀ /g lung ± s.d.	
		RSV	PIV-3
Buffer	-	3.7 ± 0.3	3.4 ± 0.3
F _{RSV-HN} PIV-3	10.0	≤1.5 ± 0.0	≤1.5 ± 0.0
F _{RSV-HN} PIV-3	1.0	≤1.5 ± 0.0	≤1.5 ± 0.0
Live RSV		≤1.5 ± 0.0	≤1.5 ± 0.0
Live PIV-3		≤1.5 ± 0.0	≤1.5 ± 0.0

^a Animals were challenged intranasally with 100 TCID₅₀ units of PIV-3 or RSV and killed 4 days later. Each value represents the mean virus lung titre of 4 animals.

CLAIMS

What we claim is:

1. A multimeric hybrid gene, comprising a gene sequence coding for an antigenic region of a protein from a first pathogen linked to a gene sequence coding for an antigenic region of a protein from a second pathogen.
2. The hybrid gene of claim 1 wherein said first and second pathogens are selected from bacterial and viral pathogens.
3. The hybrid gene of claim 2 wherein both said first and second pathogens are viral pathogens.
4. The hybrid gene of claim 1 wherein said first and second pathogens are selected from those causing different respiratory tract diseases.
5. The hybrid gene of claim 4 wherein said first and second pathogens causing different respiratory tract diseases are selected from the paramoxyviridae family of viruses.
6. The hybrid gene of claim 1 wherein at least one of said gene sequences is mutated while retaining antigenicity.
7. The hybrid gene of claim 6 wherein said mutation is at a putative pre-termination site.
8. The hybrid gene of claim 1 wherein said first pathogen is parainfluenza virus (PIV) and said second pathogen is respiratory syncytial virus (RSV).
9. The hybrid gene of claim 1, comprising at least one gene sequence coding for a parainfluenza virus (PIV) protein linked to at least one gene sequence coding for a respiratory syncytial virus (RSV) protein.
10. The hybrid gene of claim 9, wherein said parainfluenza virus protein is selected from PIV-3 F and HN proteins and said respiratory syncytial virus protein is selected from RSV G and F proteins.
11. The hybrid gene of claim 1 consisting of a gene sequence coding for a human PIV-3 F or HN protein or an

immunogenic epitope-containing fragment thereof linked to a gene sequence coding for a human RSV G or F protein or an immunogenic epitope-containing fragment thereof.

12. The hybrid gene of claim 11 which is selected from $F_{PIV-3} - F_{RSV}$, $F_{RSV} - HN_{PIV-3}$ and $F_{PIV-3} - G_{RSV}$ hybrid genes.

13. The hybrid gene of claim 1 contained in an expression vector.

14. The hybrid gene of claim 13 in the form of plasmid pAC DR7, pD2 RF-HN or pD2 F-G.

15. The hybrid gene of claim 1 further comprising at least one gene encoding at least one immunogenic and/or immunostimulating molecule.

16. Cells containing the multimeric hybrid gene of claim 1 for expression of a chimeric protein encoded by said gene.

17. The cells of claim 16 which are bacterial cells, mammalian cells, insect cells, yeast cells or fungal cells.

18. A chimeric protein, comprising an antigenic region of a protein from a first pathogen linked to an antigenic region of a protein from a second pathogen.

19. The protein of claim 18, wherein said first and second pathogens are selected from bacterial and viral pathogens.

20. The protein of claim 19 wherein both said first and second pathogens are viral pathogens.

21. The protein of claim 18, wherein said first and second pathogens are selected from those causing different respiratory tract diseases.

22. The protein of claim 21 wherein said first and second pathogens causing different respiratory tract diseases are selected from the paramoxyviridae family of viruses.

23. The protein of claim 18, wherein said first pathogen is parainfluenza virus (PIV) and said second pathogen is respiratory syncytial virus (RSV).

24. The protein of claim 18 comprising at least one parainfluenza virus (PIV) protein linked to at least one respiratory syncytial virus (RSV) protein.

25. The protein of claim 24, wherein said PIV protein is selected from PIV-3 F and HN proteins and said RSV protein is selected from RSV G and F proteins.

26. The protein of claim 18 consisting of a human parainfluenza virus-3 (PIV-3) F or HN protein or an immunogenic epitope-containing fragment thereof linked to a human respiratory syncytial virus (RSV) G or F protein or an immunogenic epitope-containing fragment thereof.

27. The protein of claim 26 which is selected from F_{PIV-3} - F_{RSV} , F_{RSV} - HN_{PIV-3} and F_{PIV-3} - G_{RSV} chimeric proteins.

28. A process for preparation of a chimeric protein which comprises:

isolating a gene sequence coding for an antigenic region of a protein from a first pathogen,

isolating a gene sequence coding for an antigenic region of a protein from a second pathogen,

linking said gene sequences to form a multimeric hybrid gene, and expressing the multimeric hybrid gene in a cellular expression system

29. The process of claim 28 wherein said multimeric hybrid gene comprises a gene sequence coding for a PIV-F or HN protein or an immunogenic epitope-containing fragment thereof linked to a gene sequence coding for a human RSV G or F protein or an epitope-containing fragment thereof.

30. The process of claim 29 wherein said multimeric hybrid gene is selected from F_{PIV-3} - F_{RSV} , F_{RSV} - HN_{PIV-3} and F_{PIV-3} - G_{RSV} hybrid genes.

31. The process of claim 30 wherein said multimeric hybrid gene is contained in an expression vector comprising plasmid pAC QR7, pD2 RF-HN or pD2 F-G.

32. The process of claim 28 wherein said cellular expression system is provided by bacterial cells,

mammalian cells, insect cells, yeast cells or fungal cells.

33. The process of claim 32 including separating a chimeric protein from a culture of said cellular expression system and purifying the separated chimeric protein.

34. A live vector for antigen delivery containing the gene of claim 1.

35. The live vector of claim 34 which is a viral vector.

36. The live vector of claim 35 wherein said viral vector is selected from poxviral, adenoviral and retroviral viral vectors.

37. The live vector of claim 34 which is a bacterial vector.

38. The live vector of claim 37 wherein said bacterial vector is selected from salmonella and mycobacteria.

39. A vaccine against diseases caused by multiple pathogenic infections, comprising a chimeric protein comprising an antigen region of a protein from a first pathogen linked to an antigenic region of a protein from a second pathogen, and a physiologically-acceptable carrier therefor.

40. The vaccine of claim 39, wherein said first and second pathogens are selected from bacterial and viral pathogens.

41. The vaccine of claim 39, which also contains at least one other immunogenic and/or immunostimulating molecule.

42. The vaccine of claim 40 wherein both said first and second pathogens are viral pathogens.

43. The vaccine of claim 39, wherein said first and second pathogens are selected from those causing upper and lower respiratory tract diseases.

44. The vaccine of claim 39, wherein said first pathogen is parainfluenza virus (PIV) and said second pathogen is respiratory syncytial virus (RSV).

45. The vaccine of claim 39 against infection by both parainfluenza virus (PIV) and respiratory syncytial virus (RSV), comprising a recombinant multimeric protein containing at least one segment consisting of a PIV protein or an immunogenic epitope-containing fragment thereof linked to at least one segment consisting of a RSV protein or an immunogenic epitope-containing fragment thereof, and a carrier therefor.

46. The vaccine of claim 45 wherein said recombinant multimeric protein is a recombinant chimeric protein containing a segment consisting of a PIV-3 F or HN protein or an immunogenic epitope-containing fragment thereof linked to a segment consisting of an RSV G or F protein or an immunogenic epitope-containing fragment thereof.

47. The vaccine of claim 46 containing at least one additional protein of PIV or RSV or chimeric protein thereof.

48. The vaccine of claim 39 wherein said carrier comprises an adjuvant.

49. The vaccine of claim 39 wherein said carrier is an ISCOM, a liposome or a microparticle.

50. The vaccine of claim 46 formulated to be administered in an injectable form, intranasally or orally.

51. The vaccine of claim 39 further comprising means for delivering said multimeric protein specifically to cells of the immune system.

52. The vaccine of claim 51 wherein said delivery means comprises a toxin molecule or an antibody.

53. A vaccine against diseases caused by multiple pathogenic infection, comprising a live vector as claimed in claim 34, and a physiologically-acceptable carrier therefor.

54. A method of immunizing a host against diseases caused by multiple pathogenic infections, which comprises

administering to a host an effective amount of a vaccine as claimed in claim 28 or 53.

55. The method of claim 54 wherein said vaccine is against diseases caused by parainfluenza virus (PIV) and respiratory syncytial virus (RSV).

56. The method of claim 55 wherein said host is selected from infants, young children, pregnant women, women of child-bearing age and susceptible persons.

57. A diagnostic reagent for detecting infection by a plurality of different pathogens in a host, comprising the chimeric protein claimed in claim 18.

58. A method of detecting infection by a plurality of different pathogens in a host, which comprises using said chimeric protein claimed in claim 18.

FIG.1A. NUCLEOTIDE SEQUENCE OF THE PIV-3 F GENE (PCR-AMPLIFIED)

AAGTCAATACCAACAACCTATTAGCAGTCATACGTCGCAAGAACAAAGAAAGAGATTCAA
 TTCAGTTATGGTTGTTGATAATCGTCAGTATGCACGTTCTTTGTTCTTTCTCTAAGTT 60

AAAGCTAAATAAGAGAAATCAAAACAATAAGGTATAGAACACCCCGAACACAATAATCAAAA
 TTTTCGATTTTATTTCTCTTTAGTTTGTGTTTCCCATATCTTGTGGGCTTGTGTTTGTGTTT 120

CATCCAAATCCCATTTTAAACAATAATCCAAAAGAGACCGGCAACACACAAGACCCAAAC
 GTAGGTTAGGTAAATAATTTGTTTAAAGGTTTCTCTGCGCCGTTGTGTTGTTCGTGGTTG 180

MET PRO THR [LEU] ILE LEU LEU ILE ILE THR THR MET ILE MET ALA [SER] SER CYS GLN
 ACAATGCCCAACTTTAATACCTGCTAATTATTACAACAATGATTATGGCATCTTCTGCCCCAA
 TGTACGGTTGAAATTTATGACGATTAAATGTTGTTACTAATAACCGTAGAAGGACGGTT 240

ILE ASP ILE THR LYS LEU GLN HIS VAL GLY VAL LEU VAL ASN SER PRO LYS GLY MET LYS
 ATACATATCACAAACAACCTACAGCATGTAGGTGTATTGGTCAACAGTCCCAAAGGATGAAG
 TATGTATAGTGTTTGTGATGTCGTACATCCACATTAACCAAGTTGTGTCAGGTTTCCCTACTTC 300

ILE SER GLN ASN PHE GLU THR ARG TYR LEU ILE LEU SER LEU ILE PRO LYS ILE GLU ASP
 ATATCACAAACAACCTTCGAAACAAGATATCTAATTTTGAGCCCTCATACCAAATAAGAGAC
 TATAGTGTTTGTGAAGCTTTGTTCTATAGATTAAACTCAGGAGTATGGTTTATCTTCTG 360

SER ASN SER CYS GLY ASP GLN GLN ILE LYS GLN TYR LYS ARG LEU LEU ASP ARG LEU ILE
 TCTAACTCTTGTGGTGACCAACAGATCAAAACAATACAAGAGGTTATTGGATAGACTGATC
 AGATTGAGAAACACCACTGGTTGTCTAGTTTGTATTGTTCTCCAATAACCTATCTGACTAG 420

FIG. 1B.

ILE PRO LEU TYR ASP GLY LEU ARG LEU GLN LYS ASP VAL ILE VAL **THR** ASN GLN GLU SER
 ATCCCTCTATATGATGGATTAAAGATTACAGAAAGATGTGATAGTAACCAATCAAGAAATCC
 TAGGGAGATATACTACTACCTAAATTCCTAATGTCCTTCTACACTATCAATGGTTAGTTCTTAGG 480
 430 440 450 460 470 480

F2-F1 CLEAVAGE SITE

ASN GLU ASN THR ASP PRO ARG THR **ARG** **SER** PHE GLY VAL ILE GLY THR ILE ALA
 AATGAATAACACTGATCCCAAGAACAAAGACCGATCCCTTTGGAGGGGTAATTGGAAACCATTTGCT
 TTAACCTTTTGTGACTAGGGTCTTGTCTGCTAGGAAACCTCCCCCATTAACCTTGGTAACGA 540
 490 500 510 520 530 540

LEU GLY VAL ALA THR SER ALA GLN ILE THR ALA ALA VAL ALA LEU VAL GLU ALA LYS GLN
 CTGGGAGTAGCAACCTCAGCACAAATTACAGCGGCAGTTGCTCTGTGTTGAAGCCAAAGCAG
 GACCCCTCATCGTTGGAGTCCGTGTTTAAATGTCGCCGTCACAGAGACCAACTTCGGTTTCGTC 600
 550 560 570 580 590 600

ALA **LYS** SER ASP ILE GLU LYS LEU LYS GLU ALA ILE ARG ASP THR ASN LYS ALA VAL GLN
 GCATAATCACACATCGAAAAAATCTCAAGAGCAATCAGGGACACAAACAAGCAGTGCAG
 CGTTTAAAGTGTTAGCTTTTGGAGTTTCTTCGTTAGTCCCTGTTGTTTTCGTCACCGTC 660
 610 620 630 640 650 660

SER VAL GLN SER SER ILE GLY ASN LEU ILE VAL ALA ILE LYS SER VAL GLN ASP TYR VAL
 TCAGTTTCAGAGCTCTATAGGAATAATTAAATAGTAAGCAATTAAATCAGTCCCAAGATTATGTC
 AGTCAAGTCTCGAGATATCCTTTTAAATTCATCGTTAAATTTAGTCAAGGTTCTAATACAG 720
 670 680 690 700 710 720

ASN **ASN** GLU ILE VAL PRO SER ILE ALA ARG LEU GLY CYS GLU ALA ALA GLY LEU GLN LEU
 AACAAACGAAATCGTGCCATCGATTGCTAGACTAGGTTGTGAAGCAGCAGGACTTCAATTA
 TTGTTGCTTTAGCACCGGTAGCTAACGATCTGATCCAAACACTTCGTCGTCCTGAGTTAAT 780
 730 740 750 760 770 780

GLY ILE ALA LEU THR GLN HIS TYR SER GLU LEU THR ASN ILE PHE GLY ASP ASN ILE GLY
 GGAAATTGCAATTAACACAGCATTAACAGCAATTAACAAACATATTTGGTGAATAACATAGGA
 CCTTAACGTAATTGTCGTAATGAGTCTTAATTGTTTGTATTAACCCACTATTGTATCCT 840
 790 800 810 820 830 840

FIG.1C.

SER LEU GLN GLU LYS GLY ILE LYS LEU GLN GLY ILE ALA SER LEU TYR ARG THR ASN ILE
 TCGTTACAGAGAAAGGAATAAAATTACAAAGGTATAGCATCATTTATACCGCACAAATATC
 AGCAATGTTCTTTTTCCTTATTTTAAATGTTCCCATATCGTAGTAATATGGCGTGTTTATAG
 850 860 870 880 890 900

THR GLU ILE PHE THR THR SER THR VAL ASP LYS TYR ASP ILE TYR ASP LEU LEU PHE THR
 ACAGAAATATTCAACAACATCAACAGTTGATGATAAATATGATATCTATGATCTATTATTACA
 TGTCTTTATAAAGTGTTGTAGTTGTCAACTATTTATCTATAGATACTAGATAATAAATGT
 910 920 930 940 950 960

GLU SER ILE LYS VAL ARG VAL ILE ASP VAL ASP LEU ASN ASP TYR SER ILE THR LEU GLN
 GAATCAATAAAGGTGAGAGTTATAGATGTTGATTTGAAATGATTACTCAATCACCCCTCCAA
 CTTAGTTATTTCCCACTCTCAATATCTACAACTAAACTTACTAATGAGTTAGTGGGAGGTT
 970 980 990 1000 1010 1020

VAL ARG LEU PRO LEU LEU THR ARG LEU LEU ASN THR GLN ILE TYR LYS VAL ASP SER ILE
 GTCAGACTCCCTTTATTAACCTAGGCTGCTGAAACACTCAGATCTACAAAGTAGATTCCCAT
 CAGTCTGAGGGAAATAATTGATCCGACGACTTGTGAGTCTAGATGTTTCAATCTAAGGTAT
 1030 1040 1050 1060 1070 1080

SER TYR ASN ILE GLN ASN ARG GLU TRP TYR ILE PRO LEU PRO SER HIS ILE MET THR LYS
 TCATATAATATCCAAACACAGAGAAATGGTATATCCCTCTTCCCAGCCCATATCATGACGAAA
 AGTATATTATAGGTTTGTCTCTTACCATATAGGGAGAAAGGTCGGTATAGTACTGCTTT
 1090 1100 1110 1120 1130 1140

GLY ALA PKE LEU GLY GLY ALA ASP VAL LYS GLU CYS ILE GLU ALA PHE SER SER TYR ILE
 GGGGCATTTCTAGGTGGAGCATGTCAAGGAATGTATAGAAAGCATTCAGCAGTTATATA
 CCCCCTAAAGATCCACCCTCGTCTACAGTTTCCTTACATATCTTCGTAAGTCGTCAATATAT
 1150 1160 1170 1180 1190 1200

CYS PRO SER ASP PRO GLY PHE VAL LEU ASN HIS GLU KET GLU SER CYS LEU SER GLY ASN
 TGCCCTTCTGATCCAGGATTTGTACTAAACCATGAAATGGAGAGGCTGCTTATCAGGAAAC
 ACGGGAGAGACTAGGTCCCTAAACATGATTTGGTACTTTACCTCTCGACGAAATAGTCCCTTG
 1210 1220 1230 1240 1250 1260

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FIG. 1D.

ILE SER GLN CYS PRO ARG THR [THR] VAL [THR] SER ASP ILE VAL PRO ARG TYR ALA PHE VAL
ATATCCCAATGTCACAAGAACCCACGGTCAACATCAGACATATGTTCCAAAGATATGCAATTCGTC
TATAGGGTTACACAGGTTCCTGGTGCCAGTGCTGTGTAACAAGGTTCTATACGTAAGCAG 1320
1270 1280 1290 1300 1310

ASN GLY GLY VAL VAL ALA ASN CYS ILE THR THR CYS THR CYS ASN GLY ILE [ASP] ASN
AATGGAGGAGTGTTGCCAAACTGTATAACAACCAACCTGTACATGCAACGGAATCGACAAT
TTACCTCCTCACCAACGTTTGACATATTGTTGGTGACATGTACGTTGCCCTTAGCTGTTA 1380
1330 1340 1350 1360 1370

ARG ILE ASN GLN PRO PRO ASP GLN GLY VAL LYS ILE THR HIS LYS GLU CYS ASN THR
AGAAATCAATCAACCAACCTGATCAAGGAGTAAATAATTAACACACATAAAGAAATGTAATACA
TCTTAGTTAGTTGGTGGAAGTTCCTCATTTTAAATATTGTGTATTTCTTACATTAATG 1440
1390 1400 1410 1420 1430 1440

ILE GLY ILE ASN GLY MET LEU PHE ASN THR ASN LYS GLU GLY THR LEU ALA PHE TYR THR
ATAGGTATCAACGGAATGCTGTTCAAATACAAATAAAGAAAGGAACCTCTTGCAATTCACACACA
TATCCATAGTTGCCCTTACGACAAGTTATGTTTATTTCTTCCCTTGAGAACGTAAGATGTGT 1500
1450 1460 1470 1480 1490

PRO ASN ASP ILE THR LEU ASN ASN SER VAL ALA LEU ASP PRO ILE ASP ILE SER ILE GLU
CCAAATGATATAACCACTAAATAATTCTGTGCACTTGATCCCAATTGACATATCAATCGAG
GGTTTACTATATTGTGATTTTAAAGACAACCGTGAACTAGGTTAACTGTATAGTTAGCTC 1560
1510 1520 1530 1540 1550

LEU ASN LYS ALA LYS SER ASP LEU GLU SER LYS GLU TRP ILE ARG ARG SER ASN GLN
CTTAACCAAGCCAAATCAGATCTAGAGGAATCAAAAGAAATGGATAAGAGGTCAAATCAA
GAATTGTTTCGGTTTAGTCTAGATCTTCTTAGTTTCTTACCTATTCTTCCAGTTTAGTT 1620
1570 1580 1590 1600 1610 1620

LYS LEU ASP SER ILE GLY ASN TRP HIS GLN SER SER THR THR ILE ILE ILE [ILE] LEU ILE
AACTAGATTCTATTGGAAACTGGCATCAATCTAGCACTACAAATCAATAATTTAATAA
TTTGATCTAAGATAACCTTTGACCGTAGTTAGATCGTGATTTAGTATTAAATAAATAT 1680
1630 1640 1650 1660 1670 1680

TM

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FIG.1E

MET ILE ILE ILE LEU PHE ILE ILE ASN VAL THR ILE ILE THR ILE ALA ILE LYS TYR TYR
 ATGATCATTATATTGTTTATATAATTAAATGTAACGATAAATTACAATTGCAATTAAAGTATTAC
 TACTAGTAATATAACAAATATTAAATTACATTGCTATTAAATGTTAACGTTAATTCAATAATG 1740
 1690 1700 1710 1720 1730

ARG ILE GLN LYS ARG ASN ARG VAL ASP GLN ASN ASP LYS PRO TYR VAL LEU THR ASN LYS
 AGAATTCAAAAGAGAAATCGAGTGGATCAAAATGACAAGCCCATATGTACTAACCAACAA
 TCTTAAGTTTTCTCTTTAGCTCACCTAGTTTACTGTTCGGTATACATGATTTGTTTGT 1800
 1750 1760 1770 1780 1790

TGACATATCTATAGATCATTAGATATTAAATTTATAAAACTT
 ACTGTATAGATATCTAGTAATCTATAATTTTAATAATTTTTTGAA 1840
 1810 1820 1830

NUCLEOTIDE SEQUENCE OF THE PIV-3 F GENE. THE cDNA SEQUENCE
 IS SHOWN IN THE PLUS (mRNA) STRAND SENSE IN THE 5' TO 3'
 DIRECTION. THE SIGNAL PEPTIDE (SP) AND THE TRANSMEMBRANE (TM)
 ANCHOR DOMAIN ARE UNDERLINED. THE PREDICTED F2-F1 CLEAVAGE SITE IS
 INDICATED BY THE ARROW (↓). AMINO ACIDS DIFFERING FROM THE
 PUBLISHED PRIMARY SEQUENCE OF THE PROTEIN ENCODED BY THE PIV-3 F
 GENE ARE BOXED.

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RESTRICTION MAP OF THE PIV-3 F GENE

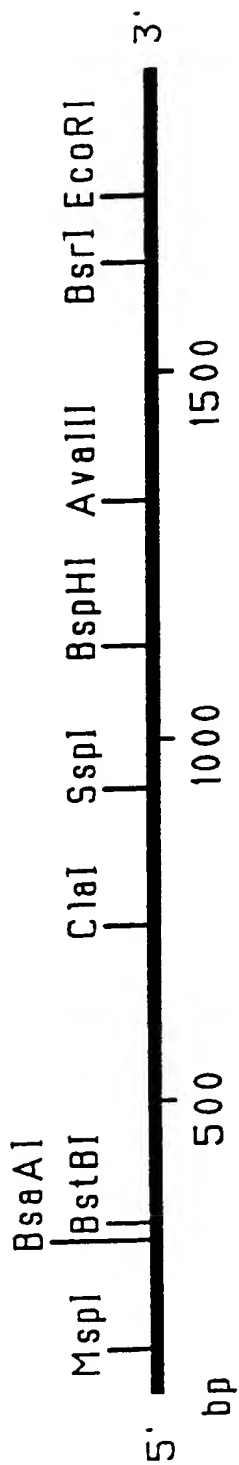


FIG.2.

THR GLN GLN MET SER ASP LEU ARG LYS PHE ILE SER GLU ILE THR ILE ARG ASN ASP ASN
 GACACAAACAGATGTCAGATCTTAGGAAATTCATTAGTGAATTAACAATTAGAAATGATAA
 CTGTGTTGTCACAGTCTAGAAATCCCTTTAAGTAATCACTTTAATGTTAAATCTTTACTATT 420
 370 380 390 400 410
 [GLN] GLU VAL [LEU] PRO GLN ARG ILE THR HIS ASP [VAL] GLY ILE LYS PRO LEU ASN PRO ASP
 TCAAGGAAGTGGCTGCCACAAAGAAATAACACATGATGTGGGTATATAAACCTTTTAAATCCAGA
 AGTTCTTCAACGACGGGTGTTCTTATTTGTGTACTACACCCCATATTTTGGAAATTTAGGTCT 480
 430 440 450 460 470
 ASP PHE TRP ARG CYS THR SER GLY LEU PRO SER LEU MET LYS THR PRO LYS ILE ARG LEU
 TGATTTTGGAGATGCCACGTCTGGTCTTCCATCTTTAATGAATACTCCAAATAAAGGTT
 ACTAAATAACCTCTACGTGCAGACCAAGGTAAGAAATTAATTTGAGGTTTATTTATTCCAA 540
 490 500 510 520 530
 MET PRO GLY PRO GLY LEU LEU ALA MET PRO THR THR VAL ASP GLY CYS [ILE] ARG THR PRO 8/39
 ATGCCAGGGCCGGGATTATTAGCTATGCCAACGACTGTGTGATGGCTGTATTCAGAACTCC
 TTACGGTCCCGGCCCTAATAATCGATACGGTTGCTGACCAACTACCGACATAGTCTTGAGG 600
 550 560 570 580 590
 SER LEU VAL ILE ASN ASP LEU ILE TYR ALA TYR THR SER ASN LEU ILE THR ARG GLY CYS
 GTCCCTTAGTTATAAATGATCTGATTTATGCTTATACCTCAAAATCTAAATTACTCGAGGTTG
 CAGGAATCAATATTACTAGACTAAATACGAATATGGAGTTTAGATTAAATGAGCTCCAAC 660
 610 620 630 640 650
 GLN ASP ILE GLY LYS SER TYR GLN VAL LEU GLN ILE GLY ILE ILE THR VAL ASN SER ASP
 TCAGGATATAGGAATAATCATATCAAGTCTTACAGATAGGGATATAAATGCTGTAAACTCAGA
 AGTCCCTATATCCCTTTTAGTATAGTTTCAGAAATGTCTATCCCTATTATTGACATTTGAGTCT 720
 670 680 690 700 710
 LEU VAL PRO ASP LEU ASN PRO ARG ILE SER HIS THR PHE ASN ILE ASN ASP ASN ARG LYS
 CTGGGTACCTGACTTAATCCAGGATCTCTCATACTTTTAAACATAAATGACAATAGGAA
 GAACCATGGACTGAATTTAGGGTCCCTAGAGATATGAAATTTGTTTACTGTATTCCTT 780
 730 740 750 760 770 780

FIG.3B.

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SRE CYS SER LEU ALA LEU LEU ASN THR ASP VAL TYR GLN LEU CYS SER THR PRO LYS VAL
 GTCA TGT TCT CTAGCAC TCC TAAATACAGATGTATATCAACTGTGTTCAACTCCCAAGT
 CAGTACAAGAGATCGTGAGGATTTATGTCTACATATAGTTGACACAAAGTTGAGGGTTTCA
 790 800 810 820 830 840

ASP GLU ARG SER ASP TYR ALA SER SER GLY ILE GLU ASP ILE VAL LEU ASP ILE VAL ASN
 TGATGAAGAATCAGATTTATGCAATCATCAGGCATAGAGATATTTGTAATGATGTTCA
 ACTACTTTCTAGTCTAATAACGTAGTAGTCCGTATCTTCTATAACATGAACCTATAACAGTT
 850 860 870 880 890 900

TYR ASP GLY SER ILE SER THR THR ARG PHE LYS ASN ASN ILE SER PHE ASP GLN PRO
 TTATGATGGCTCAATCTCAACAACAAGATTTAAGAATAATAACATTAAGCTTTGATCAACC
 AATACTACCGAGTTAGAGTTGTTGTTCTAAATTCTTATTTATTCGAAACTAGTTGG
 910 920 930 940 950 960

TYR ALA ALA LEU TYR PRO SER VAL GLY ILE TYR TYR LYS GLY LYS ILE PHE
 TTATGCTGCACCTATACCCATCTGTTGGACCAAGGATATACCTACAAAGGCAATAATATT
 AATACGACGTGATATGGGTAGACCAACC TGGTCCCTATATGATGTTTCCGTTTATTATAA
 970 980 990 1000 1010 1020

LEU GLY TYR GLY GLY LEU GLU HIS PRO ILE ASN GLU ASN **VAL** ILE CYS ASN THR THR GLY
 TCTCGGGTATGGAGGTCTTGAAACATCCCAATAAATGAGAAATGTAACTGCAACACCAACTGG
 AGAGCCCATACCTCCAGAACTTGTAGGTATTTACTCTTACATTAGACGTTGTGTGACC
 1030 1040 1050 1060 1070 1080

CYS PRO GLY LYS THR GLN ARG ASP CYS ASN GLN ALA SER HIS SER PRO TRP PHE SER ASP
 GTGTCCTCCGGGAAACAACAGAGAGACTGCAATCAGGCATCTCATAGTCCATGGTTTTCAGA
 CACAGGGGCCCTTTTGTGTCCTCTGACGTTAGTCCGTAGAGTATCAGGTACCAAAAGTCT
 1090 1100 1110 1120 1130 1140

ARG ARG MET VAL ASN SER ILE ILE VAL VAL ASP LYS GLY LEU ASN SER ILE PRO LYS LEU
 TAGGAGGATGGTCAACTCTATCATTTGTTGACAAAGGCTTAAACTCAATTCCAAATTT
 ATCCTCCTACCAAGTTGAGGATAGTAACAACAACCTGTTTCCGAATTTGAGTTAAGGTTTAA
 1150 1160 1170 1180 1190 1200

FIG.3C:

LYS VAL TRP THR ILE SER MET ARG GLN ASN TYR TRP GLY SER GLU ARG LEU LEU LEU
 GAAGGTATGGACGATATCTATGAGACAGAAATTAAGGGGTCAGAGAGGAGGTTACTTCT
 CTTCCATACCTGCTATAGATACTCTGTCTTAATGACCCCGAGTCTTCCCTTCCCAATGAAGA
 1210 1220 1230 1240 1250 1260

LEU GLY ASN LYS ILE TYR ILE TYR THR ARG SER THR SER LYS LEU GLN LEU
 ACTAGGTAAACAAGATCTATATATATACAAGATCCACAGTTGGCATAGCAAGTTACAATT
 TGATCCATTTGTTCTAGATATATATATGTTCTAGGTGTTCAACCGTATTCGTTCAATGTTAA
 1270 1280 1290 1300 1310 1320

GLY ILE ILE ASP ILE THR ASP TYR SER ASP ILE ARG ILE LYS TRP THR TRP HIS ASN VAL
 AGGAATAATTGATATTACTGATTACAGTGATATAAGGATAAATAAGGACATGGCATAATGT
 TCCTTATTAACTATAATGACTAATGTCACCTATATTCCTATTTTACCCTGTACCGTATTACA
 1330 1340 1350 1360 1370 1380

LEU SER ARG PRO GLY ASN ASN GLU CYS PRO TRP GLY HIS SER CYS PRO ASP GLY CYS ILE
 GCTATCAAGAGCAGGAAACAATGAATGTCCATGGGGACATTCATGTCAGATGGATGAT
 CGATAGTTCTGGTCCCTTTGTTACTTACAGGTACCCCTGTAAAGTACAGGTCTACCTACATA
 1390 1400 1410 1420 1430 1440

THR GLY VAL TYR THR ASP ALA TYR PRO LEU ASN PRO THR GLY SER ILE VAL SER SER VAL
 AACAGGAGTATATACATGATGCAATATCCACATCAATCCACAGGGAGCATTTGTTCATCTGT
 TTGTCCTCATATATGACTACGTATAGGTGAGTTAGGGTGTCCCTCGTAAACACAGTAGACA
 1450 1460 1470 1480 1490 1500

ILE LEU ASP SER GLN LYS SER ARG VAL ASN PRO VAL ILE THR TYR SER THR ALA THR GLU
 CATATTAGATTCAACAATAATCGAGAGTGAGTGAACCCAGTCAATACTTAACCAACCAACCGA
 GTATAAATCTAAGTGTTTATTAGCTCTCACTTGGGTCAAGTATTGAAATGAGTTGTCGTTGGCT
 1510 1520 1530 1540 1550 1560

ARG VAL ASN GLU LEU ALA ILE ARG ASN ARG THR LEU SER ALA GLY TYR THR THR SER
 AAGAGTAACGAGGCTGGCCCATCCGAAACAGAACACTCTCAGCTGGGATATACAAACAACAAG
 TTCTCATTTGCTCGACCGGTAGGCTTTTGCTCTGTGAGAGTCCGACCTATATGTTGTTGTTTC
 1570 1580 1590 1600 1610 1620

FIG.3D.

CYS ILE THR HIS TYR ASN LYS GLY TYR CYS PHE HIS ILE VAL GLU ILE ASN GLN LYS SER
 CTGCATCACACACTATACAAAGGATATTGTTTTCATATAGTAGAAATAAATCAGAAAAAG
 GACGTAGTGTGTGATATTGTTTCCCTATAACAAGTATATCATCTTTATTTAGTCTTTTC 1680
 1630 1640 1650 1660 1670 1680
 LEU ASN THR LEU GLN PRO MET LEU PHE LYS THR GLU VAL PRO LYS SER CYS SER ***
 CTTAAACACACTTCAACCCATGTTGTTCAAGACAGAGGTTCCCAAAGCTGTCAGTTAATC
 GAATTTGTGTGAAGTTGGGTACAACAAGTCTCTCCCAAGGTTTTCGACGTCCAATTAG 1740
 1690 1700 1710 1720 1730 1740
 A T A A T T A A C C G C A A T A T G C A T T A A C C T A T C T A T A A T A C A A G T A T A T G A T A A G T A A T C A G C
 T A T T A A T T G G C G T T A T A C G T A A T T G G A T A G A T A T T A T G T T C A T A T A C T A T T C A T T A G T C G 1800
 1750 1760 1770 1780 1790 1800
 A A T C A G A C A A T A G A C A A A A G G G A A A T A T A A A A A
 T T A G T C T G T T A T C T G T T T T C C C T T T A T A T T T T 1830
 1810 1820 1830

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NUCLEOTIDE SEQUENCE OF THE PIV-3 HN GENE. THE cDNA SEQUENCE IS SHOWN IN THE PLUS (mRNA) STRAND SENSE IN THE 5' TO 3' DIRECTION. THE TRANSMEMBRANE (TM) ANCHOR DOMAIN IS UNDERLINED. AMINO ACIDS DIFFERING FROM THE PUBLISHED PRIMARY SEQUENCE OF THE PROTEIN ENCODED BY THE PIV-3 HN GENE ARE BOXED.

FIG.3E.

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RESTRICTION MAP OF THE PIV-3 HN GENE

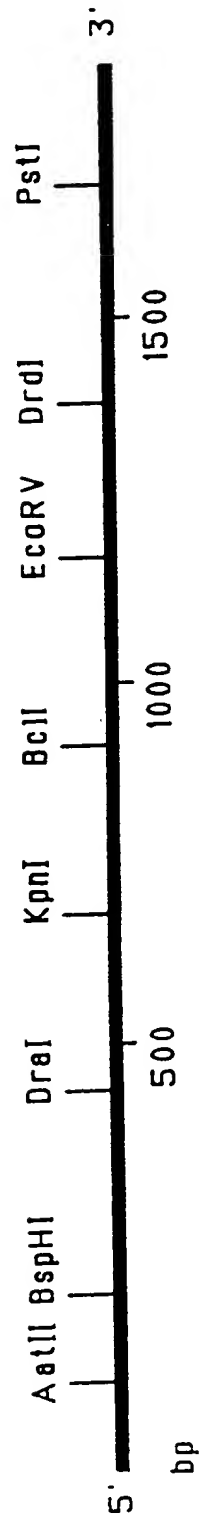


FIG.4.

FIG.5A.

NUCLEOTIDE SEQUENCE OF THE RSV F GENE.

5' MET GLU LEU [PRO] ILE LEU LYS ALA ASN ALA ILE THR THR ILE LEU ALA [ALA] VAL THR PHE
 ATGGAGGTTGGCCAAATCCCTCAAGCAAAATGCAATACCCACAAATCCCTCGCTGCGAGTCAACATTT
 TACCTCAACGCGTTAGGAGTTTTCGTTTACGTTTAAATGGTGTAGGAGCGGACGTCAGTGTA
 10 20 30 40 50 60
 CYS PHE [SER] SER GLN ASN ILE THR GLU GLU PHE TYR GLN SER THR CYS SER ALA VAL
 TGGCTTTGGCTTCTTAGTCAAAACATCACTGAAAGAAATTTTATCAATCAACATGCGAGTGCAGTT
 ACGAAACGGAAGATCAGTTTGTAGTGACTTCTTAAATAGTTAGTTGTACGTCACGTCACAA
 70 80 90 100 110 120
 SER LYS GLY TYR LEU SER ALA LEU ARG THR GLY TRP TYR THR SER VAL ILE THR ILE GLU
 AGCAAGGCTATCTTAGTGCTCTAAGAACTGGTTGGTATACCTAGTGTGTTATTAACCTATAGAA
 TCGTTTCCGATAGAAATCAGAGATTCTTGACCAACCAATATGATCAACAAATATGATATCTT
 130 140 150 160 170 180
 LEU SER ASN ILE LYS GLU ASN LYS CYS ASN GLY THR ASP ALA LYS VAL LYS LEU [MET] LYS
 TTAAGTAATATCAAGGAAATAAGTGTAATGGAACAGATGCTAAGGTAAATAATGATGAA
 AATTCAATTATAGTTCCCTTTTATTCACATTAACCTTGCTACGATTCCATTTTAACTACTTT
 190 200 210 220 230 240
 GLN GLU LEU ASP LYS TYR LYS ASN ALA VAL THR GLU LEU GLN LEU MET GLN SER THR
 CAAGAAATTAGATAAATAAATAATGCTGTAAACAGAAATGCGAGTTGCTCATGCAAGACACA
 GTTCTTAAATCTATTTATAATTTTACGACATTTGCTTAACGTCACGAGTACGTTTCGTGT
 250 260 270 280 290 300
 PRO [ALA] [ALA] ASN ASN ARG ALA ARG ARG GLU LEU PRO ARG PHE MET ASN TYR THR LEU ASN
 CCAAGCAGCAACAATCGAGCCAGAGAACTACCAAGGTTTATGAAATTAACACTCAAC
 GGTCCGTCGTTTGTAGCTCGGTCCTTCTTCCAAATACCTTAATAATGAGTTG
 310 320 330 340 350 360

F2-F1 CLEAVAGE SITE

三

TWO

5

ARG

THE

.

FIG. 5B.

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ILE ASN ASP MET PRO ILE THR ASN ASP GLN LYS LYS LEU MET SER ASN ASN VAL GLN ILE
ATCAATGATATGCTTATAACAATGATCAGAAAAGTTAATGTCACAACAATGTTCAATAA
TAGTTACTATACGGATATGTTTACTAGTCTTTTTCATTTACAGGTTGTTACAAAGTTTAT 840
790 800 810 820 830

VAL ARG GLN GLN SER TYR SER ILE MET SER ILE LYS GLU VAL LEU ALA TYR VAL
GTTAGACAGCAAGTTACTCTATCATGTCCTAATAAAGAGGAAAGTCTTTAGCATATGTA
CAATCTGTCTGTTTCAATGAGATAGTACAGGATTTATTTCTCTTCAGAAATCGTATACAT 900
850 860 870 880 890

VAL GLN LEU PRO LEU TYR GLY VAL ILE ASP THR PRO CYS TRP LYS LEU HIS THR SER PRO
GTACAAATTACCACTATATGTTGTTGATAGATACACCTTGTGGAATTTACACACATCCCCCT
CATGTTAATGTTGATATACCACTATCTATGTTGGAACAACCTTTTAAATGTTGTAGGGGA 960
910 920 930 940 950

LEU CYS THR THR ASN THR LYS GLU GLY SER ASN ILE CYS LEU THR ARG THR ASP ARG GLY
CTATGTACAAACCAACAACAAGAGGGTCAACAATCTGTTTAAACAAGAACTGACAGAGGA
GATACATGTTGTTGTTTCTTCCCAAGTTTGTAGACAAATTTGTTCTTGACTGTCTCCT 1020
970 980 990 1000 1010 1020

TRP TYR CYS ASP ASN ALA GLY SER VAL SER PHE PHE PRO GLN ALA GLU THR CYS LYS VAL
TGGTACTGTGACCAATGCAAGGATCAGTATCTTTCTTCCCAACAAGCTGAAACATGTAAGTT
ACCATGACACTGTTACGTTCCCTAGTCAATAGAAAGAGGGTGTTCGACTTTGTTACATTTCAA 1080
1030 1040 1050 1060 1070 1080

GLN SER ASN ARG VAL PHE CYS ASP THR MET ASN SER LEU THR LEU PRO SER GLU VAL ASN
CAATCGAATCGAGTATTTTGTGACACAATGAAACAGTTTAAACATTAACCAAGTGAAAGTAAAT
GTTAGCTTAGCTCATAAACAACACTGTGTTACTTGTCAAAATGTAATGGTTTCACTTCATTTA 1140
1090 1100 1110 1120 1130 1140

LEU CYS ASN VAL ASP ILE PHE ASN PRO LYS TYR ASP CYS LYS ILE MET THR SER LYS THR
CTCTGCAATGTTGACATATTTCAATCCCAATAATGTAATGTAATGACTTCAAAAACA
GAGACGTTACCAACTGTATTAAGTTAGGGTTTATACCTAACCATTTTAAATACTGAGTTTGT 1200
1150 1160 1170 1180 1190 1200

```

FIG.5C.

ASP VAL SER SER VAL ILE THR SER LEU GLY ALA ILE VAL SER CYS TYR GLY LYS THR
 GATGTAAGCAGCTCCGTTATCACAATCTCTAGGAGCCCATTTGTCATGCTATGGCAAACT
 CTACATTCGTCGAGGCAATAGTGTAGAGATCCCTCGGTAAACACAGTACGATACCGTTTGA
 1210 1220 1230 1240 1250 1260

LYS CYS THR ALA SER ASN LYS ASN ARG GLY ILE ILE LYS THR PHE SER ASN GLY CYS ASP
 AAATGTAAGCAGCAATCCCAATAAATAATCGTGGGAATCATAAAGACATTTTCTAAACGGGTGAT
 TTTACATGTCGTAGGTTATTTTAAAGCACCCTTAGTATTTCTGTAAAGATTTGCCCACTA
 1270 1280 1290 1300 1310 1320

TYR VAL SER ASN LYS GLY VAL ASP THR VAL SER VAL GLY ASN THR LEU TYR TYR VAL ASN
 TATGTATCAATAAAGGGGTGGACACTGTGTCGTAGGTAAACACATTTATATATGTAAT
 ATACATAGTTTATTTCCCACTGTTGACACAGACATCCCATTTGTATAATATACATTTA
 1330 1340 1350 1360 1370 1380

LYS GLN GLU GLY LYS SER LEU TYR VAL LYS GLY GLU PRO ILE ILE ASN PHE TYR ASP PRO
 AAGCAAGAAAGCAGCAAAAGTCTCTATGTAAAGGTGAACCAATAATAATTTCTATGACCCCA
 TTCGTTCTTCCGTTTTCAGAGATACATTTTCCCACTTGGTTATTTTAAAGATACCTGGGT
 1390 1400 1410 1420 1430 1440

LEU VAL PHE PRO SER ASP GLU PHE ASP ALA SER ILE SER GLN VAL ASN GLU LYS ILE ASN
 TTAGTATTTCCCTCTCTGATGAATTTGATGCAATCAATATCTCAAGTCAACGAGAGATTAAC
 AATCATAAAGGGGAGACTACTTAAACTACGTAAGTTATAGAGTTTCAGTTGCTCTTCTAATTG
 1450 1460 1470 1480 1490 1500

GLN SER LEU ALA PHE ILE ARG LYS SER ASP GLU LEU LEU HIS ASN VAL ASN ALA GLY LYS
 CAGAGTTTAGCATTTATTCGTAAATCCGATGAATTTATACATAATGTAAATGCTGGTAAAC
 GTCCTCAAAATCGTAAATAAGCAATTTAGGCTACTTAATAATGTTATTCATTTACGACCATTT
 1510 1520 1530 1540 1550 1560

SER THR THR ASN ILE MET ILE THR THR ILE ILE GLU ILE ILE VAL ILE LEU LEU SER
 TCAACCAACAATATCATGATAAATCTACTATAATATAGAGATTTATAGTAATTTGTTATCA
 AGTTGGTGTATTATAGTACTATTGATGATGATTAATATCTCTAATATCATTAACAATAGT
 1570 1580 1590 1600 1610 1620

FIG.5D.

LEU ILE ALA VAL GLY LEU LEU LEU TYR CYS LYS ALA ARG SER THR PRO VAL THR LEU SER
 TTAATTGGCTGTTGGACTGCTCCTATACCTGTAAGGCCAGAGCACACCCAGTCACACTAAGC
 AATTACGACACCACTGACGAGGATATGACATTCGGGTTCCGGTCTTCGTGTCAGTGTGATTCG 1680
 1630 1640 1650 1660 1670 1680
 LYS, ASP GLN LEU SER GLY ILE ASN ASN ILE ALA PHE SER ASN
 AAGGATCAACTGAGTGGTATAATAATAATATTGCAATTTAGTAACCTGAAATAAATAATAGCACCT
 TTCCTAGTTGACTCACCATAATTATTATTATAACGTAAATTCATTGACTTATTTTATTCGTGGA 1740
 1690 1700 1710 1720 1730 1740
 AATCATGTTCTTACAAATGGTTTACTATCTGCTCATAGACACAACCCATCTCATTCATTGGATTT
 TTAGTACAAGAAATGTTACCAAAATGATAGACGAGTATCTGTGTTGGGTAGATAGTAACCTAAA 1800
 1750 1760 1770 1780 1790 1800
 TCTTAAATACTGAACCTTCATCGAAACTCTTATCTATTAACCATCTCATTACACTATTTA
 AGAATTTTAGACTTGAAGTAGCTTTGAGAAATAGATATTGTTGTTAGAGTGAATGTGATAAAT 1850
 1810 1820 1830 1840 1850 1860
 AGTAGATTCCCTAGTTTATAGTTATAT 3'
 TCATCTAAGGATCAAAATATCAATATA 1880

NUCLEOTIDE SEQUENCE OF THE RSV F GENE. THE cDNA SEQUENCE IS SHOWN IN THE PLUS (mRNA) STRAND SENSE IN THE 5' TO 3' DIRECTION. THE SIGNAL PEPTIDE (SP) AND THE TRANSMEMBRANE (TM) ANCHOR DOMAIN ARE UNDERLINED. THE PREDICTED F2-F1 CLEAVAGE SITE IS INDICATED BY THE ARROW (↓). AMINO ACIDS DIFFERING FROM THE PUBLISHED PRIMARY SEQUENCE OF THE PROTEIN ENCODED BY THE RSV F GENE ARE BOXED.

FIG. 5E.

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RESTRICTION MAP OF THE RSV F GENE

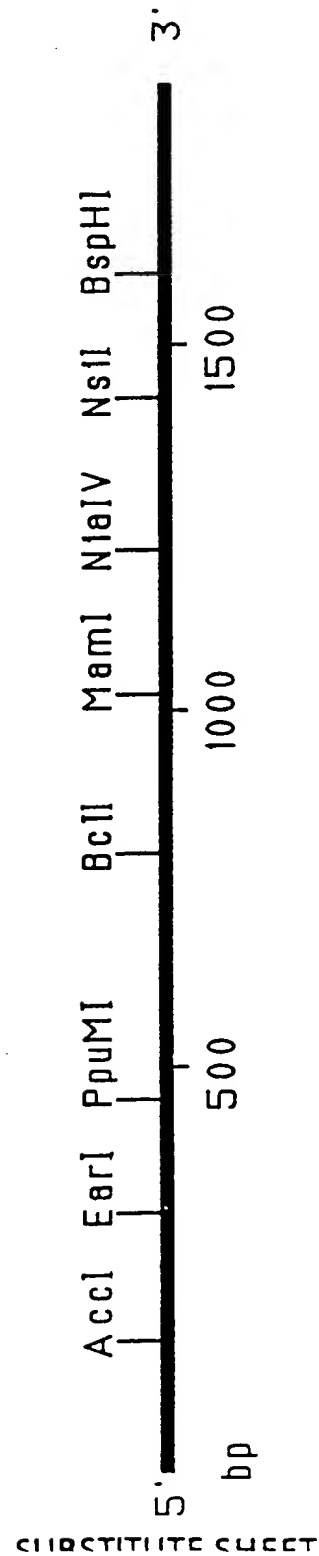


FIG.6.

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FIG.7A.

NUCLEOTIDE SEQUENCE OF THE RSV G GENE

MET SER LYS ASN LYS ASP GLN ARG
 T G C A A A C A T G T C C A A A A C A A G G A C C A A C G
 A C G T T T G T A C A G G T T T T T G T T C C T G G T T G C
 10 20 30

THR ALA LYS THR LEU GLU **LYS** THR TRP ASP
 C A C C G C T A A G A C A C T A G A A A A G A C C T G G G A
 G T G G C G A T T C T G T G A T C T T T C T G G A C C C T
 40 50 60

THR LEU ASN HIS LEU LEU PHE ILE SER SER
 C A C T C T C A A T C A T T T A T T A T T C A T A T C A T C
 G T G A G A G T T A G T A A A T A A T A A G T A T A G T A G
 70 80 90

GLY LEU TYR LYS LEU ASN LEU LYS SER VAL
 G G G C T T A T A T A A G T T A A A T C T T A A A T C T G T
 C C C G A A T A T A T T C A A T T T A G A A T T T A G A C A
 100 110 120

———— TM ————
 ALA GLN ILE THR LEU SER ILE LEU ALA MET
 A G C A C A A A T C A C A T T A T C C A T T C T G G C A A T
 T C G T G T T T A G T G T A A T A G G T A A G A C C G T T A
 130 140 150

ILE ILE SER THR SER LEU ILE ILE **THR** ALA
 G A T A A T C T C A A C T T C A C T T A T A A T T A C A G C
 C T A T T A G A G T T G A A G T G A A T A T T A A T G T C G
 160 170 180

ILE ILE PHE ILE ALA SER ALA ASN HIS LYS
 C A T C A T A T T C A T A G C C T C G G C A A A C C A C A A
 G T A G T A T A A G T A T C G G A G C C G T T T G G T G T T
 190 200 210

VAL THR **LEU** THR THR ALA ILE ILE GLN ASP
 A G T C A C A C T A A C A A C T G C A A T C A T A C A A G A
 T C A G T G T G A T G T T G A C G T T A G T A T G T T C T
 2 230 240

ALA THR SER GLN ILE LYS ASN THR THR PRO
 T G C A A C A A G C A G A T C A A G A A C A C A A C C C C
 A C G T T G T T C G T C T A G T T C T T G T G T T G G G G
 250 260 270

THR TYR LEU THR GLN **ASP** PRO GLN LEU GLY
 A A C A T A C C T C A C T C A G G A T C C T C A G C T T G G
 T T G T A T G G A G T G A G T C C T A G G A G T C G A A C C
 280 290 300

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FIG.7B.

```

      ILE  SER  PHE  SER  ASN  LEU  SER  GLU  ILE  THR
A A T C A G C T T C T C C A A T C T G T C T G A A T T A C
T T A G T C G A A G A G G T T A G A C A G A C T T T A A T G
                               310                               320                               330

      SER  GLN  THR  THR  THR  ILE  LEU  ALA  SER  THR
A T C A C A A A C C A C C A C C A T A C T A G C T T C A A C
T A G T G T T T G G T G G T G G T A T G A T C G A A G T T G
                               340                               350                               360

      THR  PRO  GLY  VAL  LYS  SER  ASN  LEU  GLN  PRO
A A C A C C A G G A G T C A A G T C A A A C C T G C A A C C
T T G T G G T C C T C A G T T C A G T T T G G A C G T T G G
                               370                               380                               390

      THR  THR  VAL  LYS  THR  LYS  ASN  THR  THR  THR
C A C A A C A G T C A A G A C T A A A A A C A C A A C A A C
G T G T T G T C A G T T C T G A T T T T T G T G T T G T T G
                               400                               410                               420

      THR  GLN  THR  GLN  PRO  SER  LYS  PRO  THR  THR
A A C C C A A A C A C A A C C C A G C A A G C C C A C T A C
T T G G G T T T G T G T T G G G T C G T T C G G G T G A T G
                               430                               440                               450

      LYS  GLN  ARG  GLN  ASN  LYS  PRO  PRO  ASN  LYS
A A A A C A A C G C C A A A A C A A A C C A C C A A A C A A
T T T T G T T G C G G T T T T G T T T G G T G G T T T G T T
                               460                               470                               480

      PRO  ASN  ASN  ASP  PHE  HIS  PHE  GLU  VAL  PHE
A C C C A A T A A T G A T T T T C A C T T C G A A G T G T T
T G G G T T A T T A C T A A A A G T G A A G C T T C A C A A
                               490                               500                               510

      ASN  PHE  VAL  PRO  CYS  SER  ILE  CYS  SER  ASN
T A A C T T T G T A C C C T G C A G C A T A T G C A G C A A
A T T G A A A C A T G G G A C G T C G T A T A C G T C G T T
                               520                               530                               540

      ASN  PRO  THR  CYS  TRP  ALA  ILE  CYS  LYS  ARG
C A A T C C A A C C T G C T G G G C T A T C T G C A A A A G
G T T A G G T T G G A C G A C C C G A T A G A C G T T T T C
                               550                               560                               570

      ILE  PRO  ASN  LYS  LYS  PRO  GLY  LYS  LYS  THR
A A T A C C A A A C A A A A A A C C A G G A A A G A A A A C
T T A T G G T T T G T T T T T T G G T C C T T T C T T T T G
                               580                               590                               600

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FIG.7C.

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      THR  THR  LYS  PRO  THR  LYS  LYS  PRO  THR  PHE
C A C C A C C A A G C C T A C A A A A A A C C A A C C T T
G T G G T G G T T C G G A T G T T T T T T T G G T G G A A
      610                      620                      630

      LYS  THR  THR  LYS  LYS  ASP  LEU  LYS  PRO  GLN
C A A G A C A A C C A A A A A A G A T C T C A A A C C T C A
G T T C T G T T G G T T T T T T C T A G A G T T T G G A G T
      640                      650                      660

      THR  THR  LYS  PRO  LYS  GLU  VAL  PRO  THR  THR
A A C C A C T A A A C C A A A G G A A G T A C C C A C C A C
T T G G T G A T T T G G T T T C C T T C A T G G G T G G T G
      670                      680                      690

      LYS  PRO  THR  GLU  GLU  PRO  THR  ILE  ASN  THR
C A A G C C C A C A G A A G A G C C A A C C A T C A A C A C
G T T C G G G T G T C T T C T C G G T T G G T A G T T G T G
      700                      710                      720

      THR  LYS  THR  ASN  ILE  THR  THR  THR  LEU  LEU
C A C C A A A A C A A A C A T C A C A A C T A C A C T G C T
G T G G T T T T G T T T G T A G T G T T G A T G T G A C G A
      730                      740                      750

      THR  ASN  ASN  THR  THR  GLY  ASN  PRO  LYS  LEU
C A C C A A C A A C A C C A C A G G A A A T C C A A A A C T
G T G G T T G T T G T G G T G T C C T T T A G G T T T T G A
      760                      770                      780

      THR  SER  GLN  MET  GLU  THR  PHE  HIS  SER  THR
C A C A A G T C A A A T G G A A A C C T T C C A C T C A A C
G T G T T C A G T T T A C C T T T G G A A A G G T G A G T T G
      790                      800                      810

      SER  SER  GLU  GLY  ASN  LEU  SER  PRO  SER  GLN
C T C C T C C G A A G G C A A T C T A A G C C C T T C T C A
G A G G A G G C T T C C G T T A G A T T C G G G A A G A G T
      820                      830                      840

      VAL  SER  THR  THR  SER  GLU  HIS  PRO  SER  GLN
A G T C T C C A C A A C A T C C G A G C A C C C A T C A C A
T C A G A G G T G T T G T A G G C T C G T G G G T A G T G T
      850                      860                      870

      PRO  SER  SER  PRO  PRO  ASN  THR  THR  ARG  GLN
A C C C T C A T C T C C A C C C A A C A C A A C A C G C C A
T G G G A G T A G A G G T G G G T T G T G T T G T G C G G T
      880                      890                      900

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G TAGTTATTAAAAAAAAAAAA
CATCAATAATTTTTTTTTTTT
910 920

NUCLEOTIDE SEQUENCE OF THE RSV G GENE. THE cDNA
SEQUENCE IS SHOWN IN THE PLUS (mRNA) STRAND
SENSE IN THE 5' TO 3' DIRECTION. THE TRANSMEMBRANE
(TM) ANCHOR DOMAIN IS UNDERLINED. AMINO ACIDS
DIFFERING FROM THE PUBLISHED PRIMARY SEQUENCE OF
THE PROTEIN ENCODED BY THE RSV G GENE ARE BOXED.

FIG.7D.

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RESTRICTION MAP OF RSV G GENE

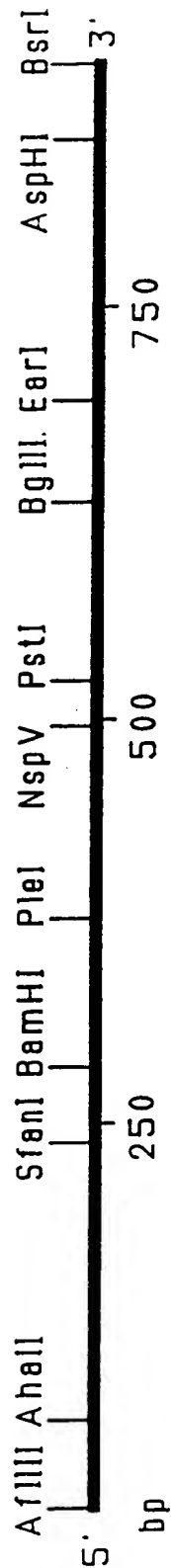


FIG.8.

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Construction of a Bluescript-based expression vector containing the chimeric F_{PIV-3}-F_{RSV} gene with the 5' untranslated region of the PIV-3 F gene intact but lacking the nucleotide sequences coding for the hydrophobic anchor domains and cytoplasmic tails of both the PIV-3 and RSV F genes.

Step 1: Preparation of the plasmid containing the modified PIV-3 F gene

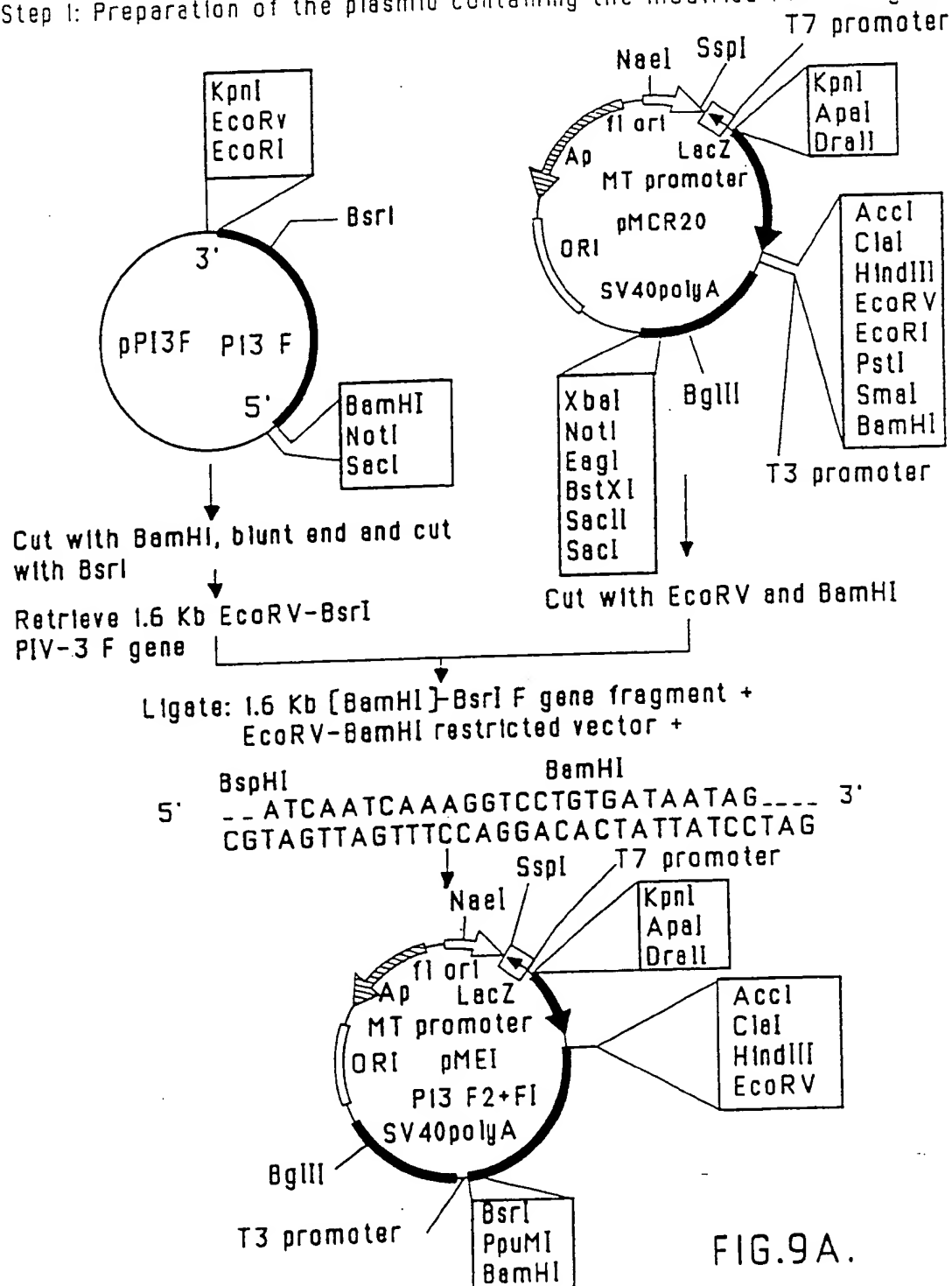
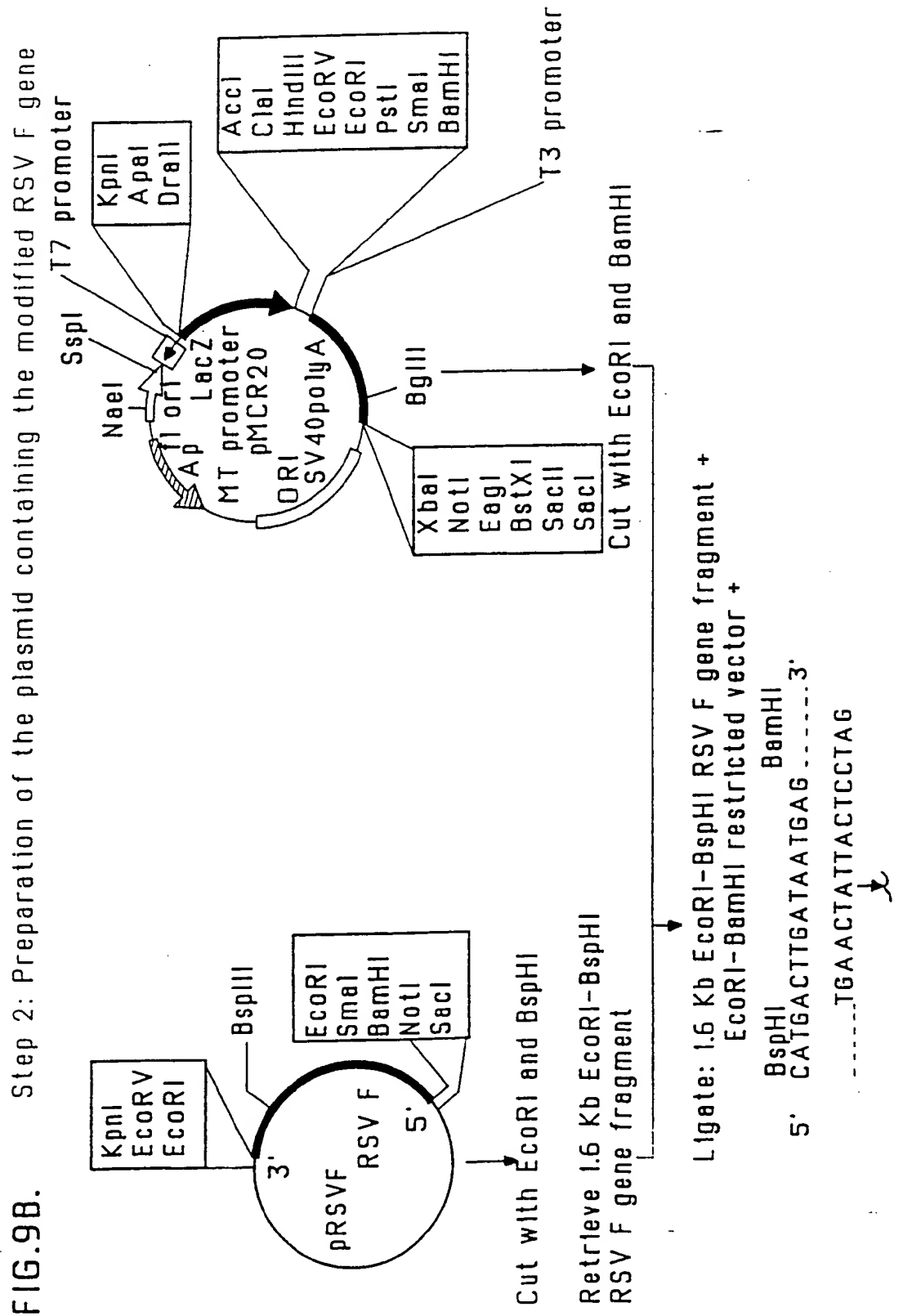
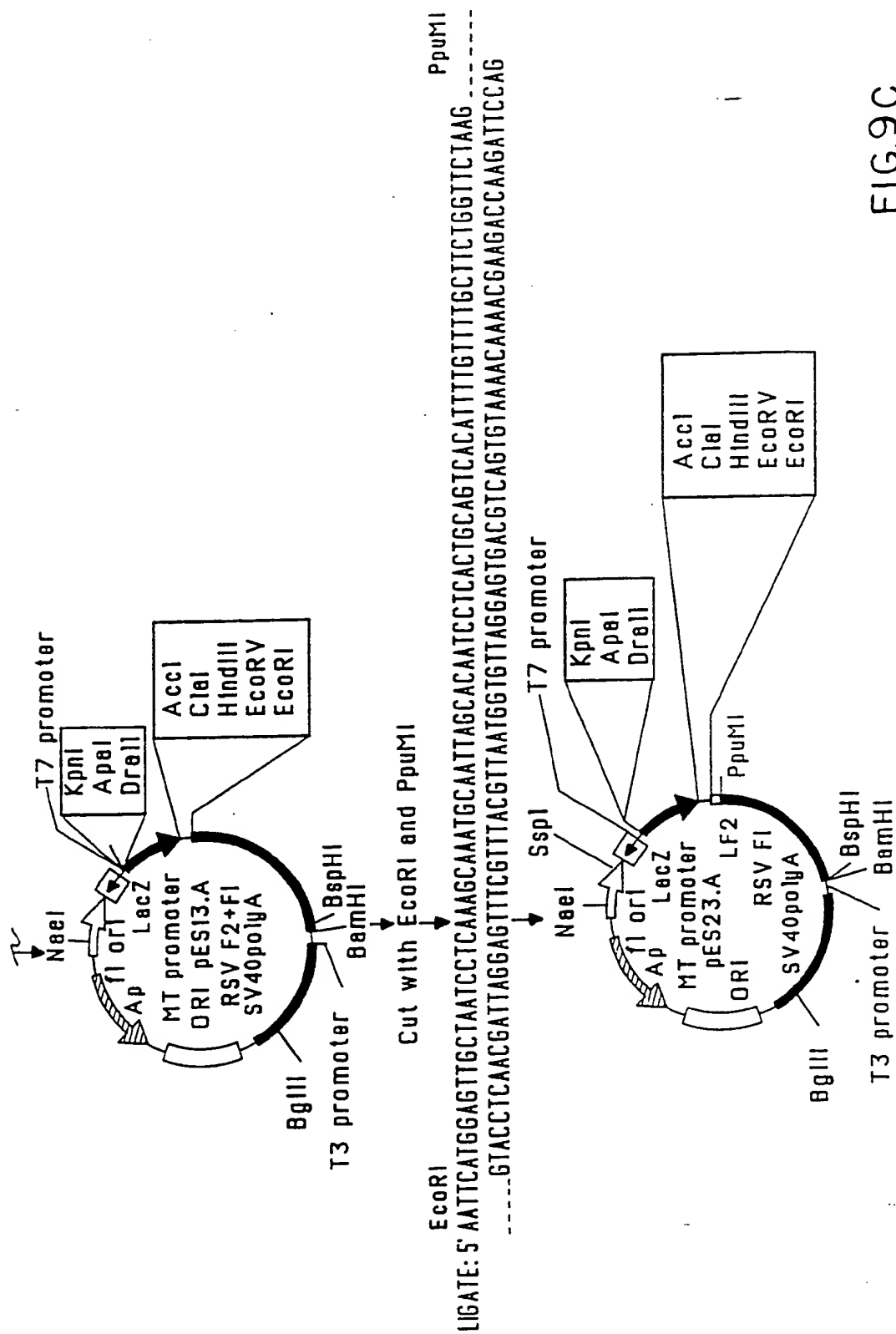


FIG.9A.

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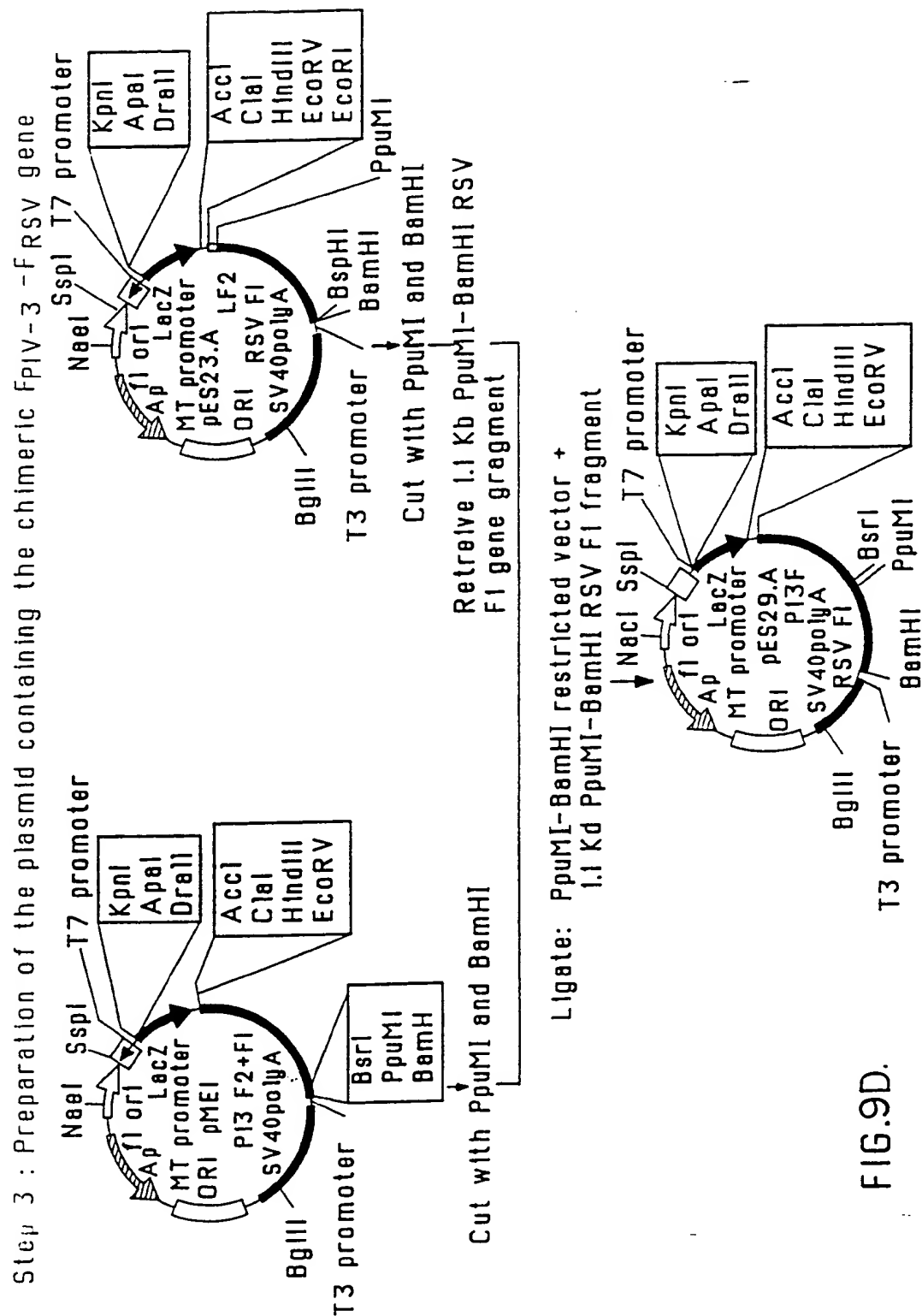


FIG.9D.

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Construction of a Bluescript-based expression vector containing the PIV-3 F gene lacking the 5' untranslated sequence and transmembrane anchor and cytoplasmic tail coding regions.

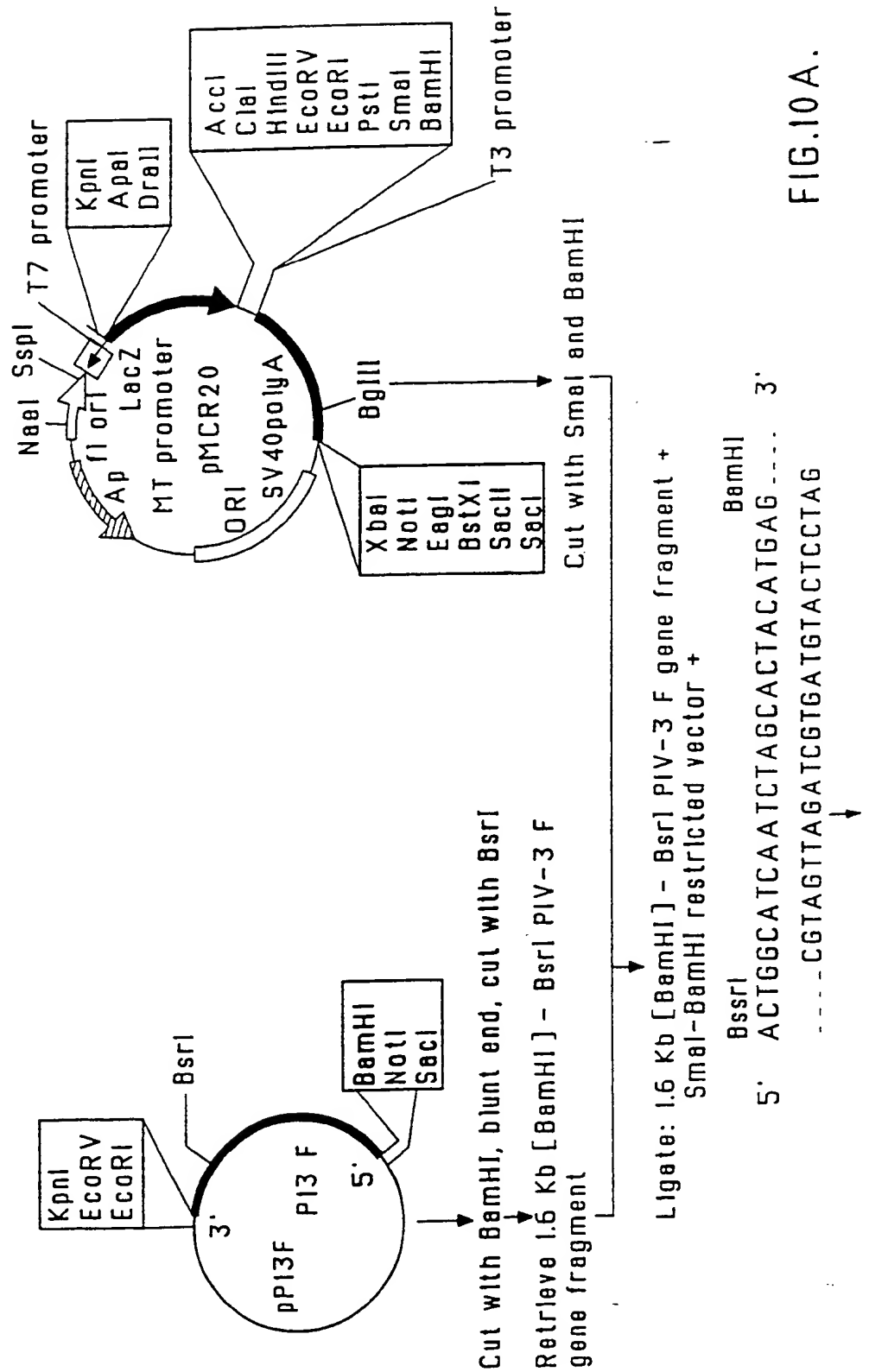
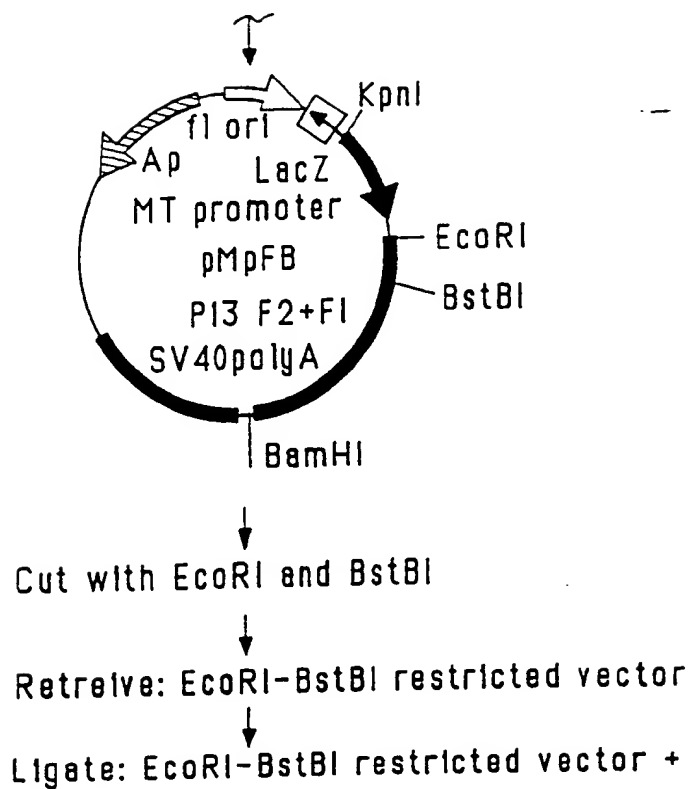


FIG.10A.

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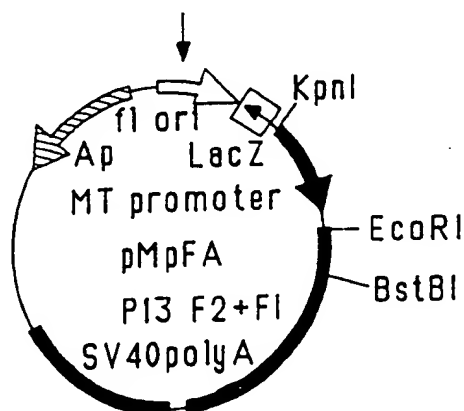
FIG.10B.



EcoRI

PpuMI

AATTCATGCCAACTTTAATACTGCTAATTATTACAACAATGATTATGG
 CATCTTCCTGCCAAATAGATATCACAAAACCTACAGCAATGTAGGTGTA
 TTGGTCAACAGTCCCAAAGGGATGAAGATATCACAAAACCT 3'
 GTACGGTTGAAATTATGACGATTAATAATGTTGTTACTAATACC
 GTAGAAGGACGGTTTATCTATAGTGTTTTGATGTCGTACATCCACATA
 ACCAGTTGTCAGGGTTTCCCTACTTCTATAGTGTTTTGAAGCTT



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Construction of the chimeric FPIV-3-FRSV gene consisting of the truncated PIV-3 F gene devoid of the 5' untranslated region linked to the truncated RSV F1 gene.

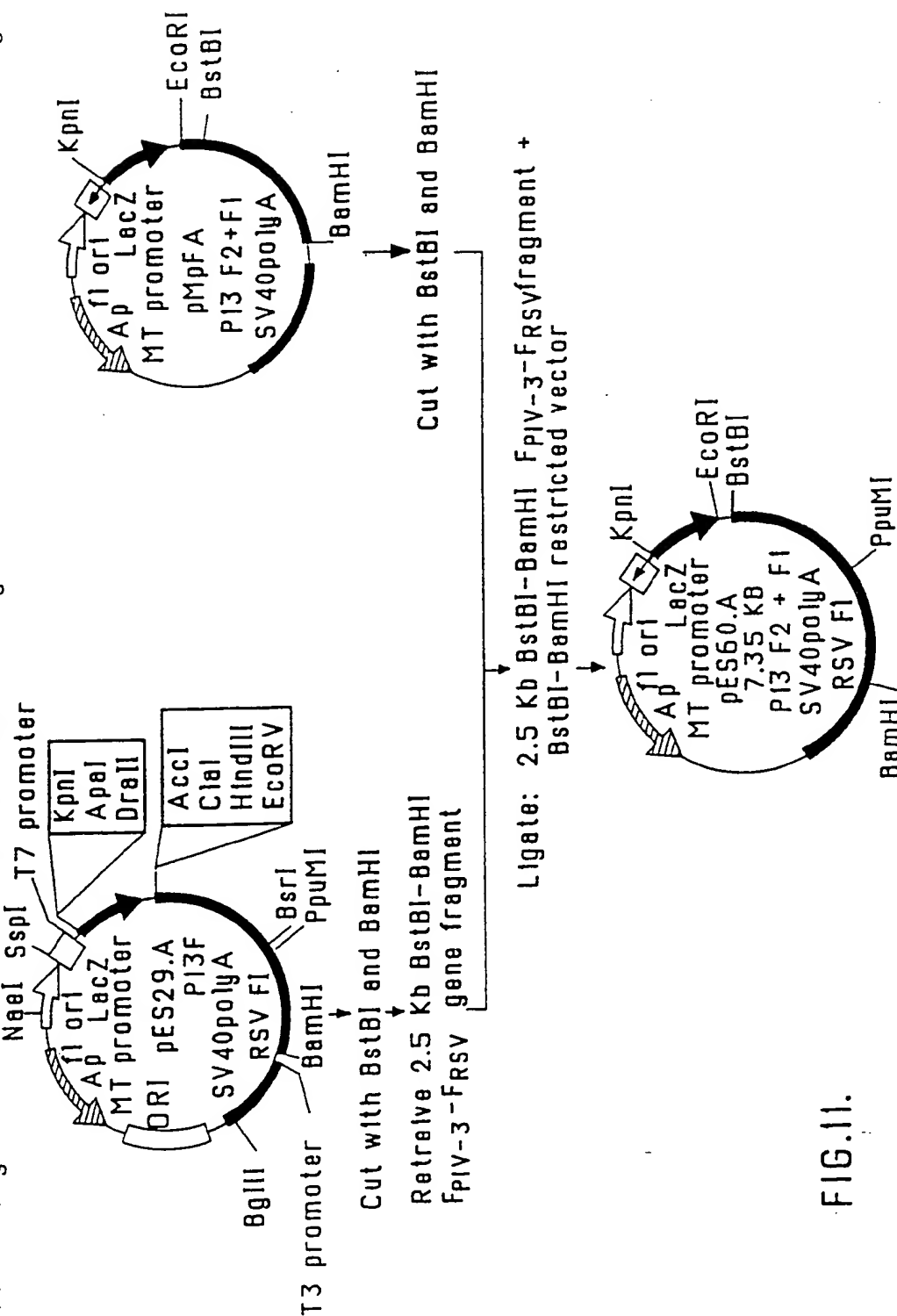
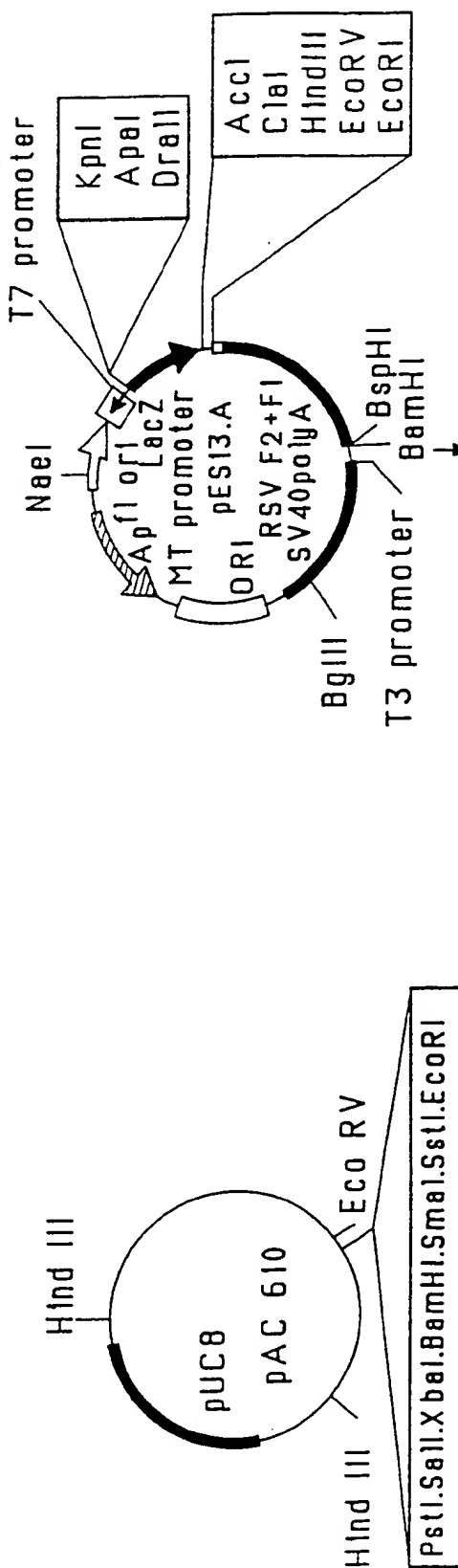


FIG.11.

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FIG.12A. Construction of the modified pAc 610 baculovirus expression vector containing the chimeric FpIV-3-FRSV gene consisting of the PIV-3 F gene lacking both the 5' untranslated sequence as well as the transmembrane and cytoplasmic tail coding regions linked to the truncated RSV F1 gene



Cut with EcoRI and BamHI
Retreive 1.6 Kb EcoRI-BamHI
RSV F gene fragment

Cut with EcoRV and BamHI

Ligate: 1.6 Kb EcoRI-BamHI RSV F gene fragment +
EcoRV EcoRV-BamHI restricted vector +

EcoRI
5' ATCATGGAGATAATTAATGATAACCATCTCGCAATAAATAAGTATTTTACTGTTTCGTACAGTTTGTGTAATAAAAACCTATAAATAG 3'
TAGTACCTCTATTAAATTTTACTATTGGTAGACGCTTATTATTTCATAAAATGACAAAAGCATTGTCANAAACATTATTTTTTGGATATTATCTTAA

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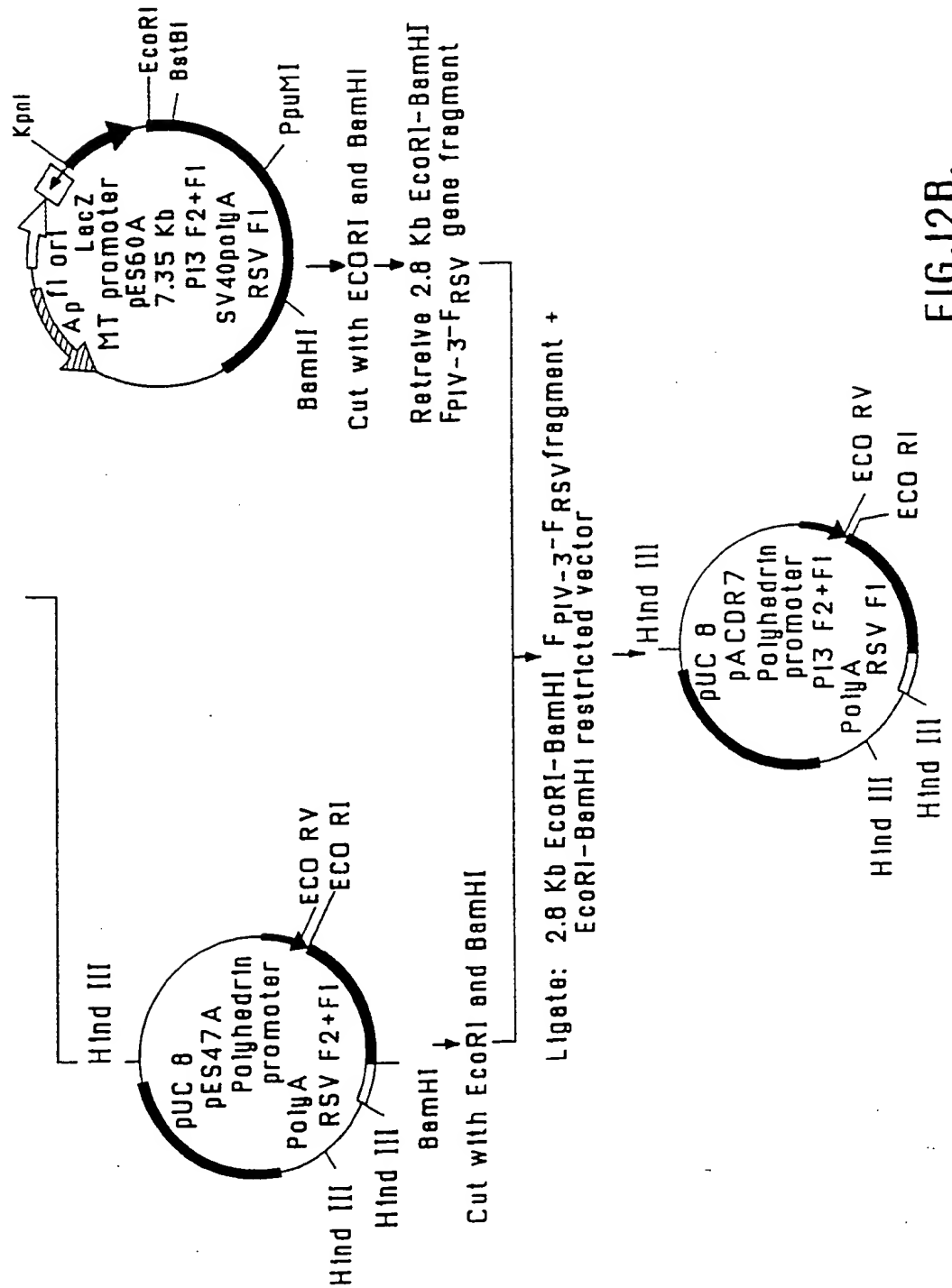


FIG. 12B.

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FIG.13

IMMUNOBLOTS OF CELL LYSATES FROM Sf9 CELLS
INFECTED WITH RECOMBINANT BACULOVIRUSES

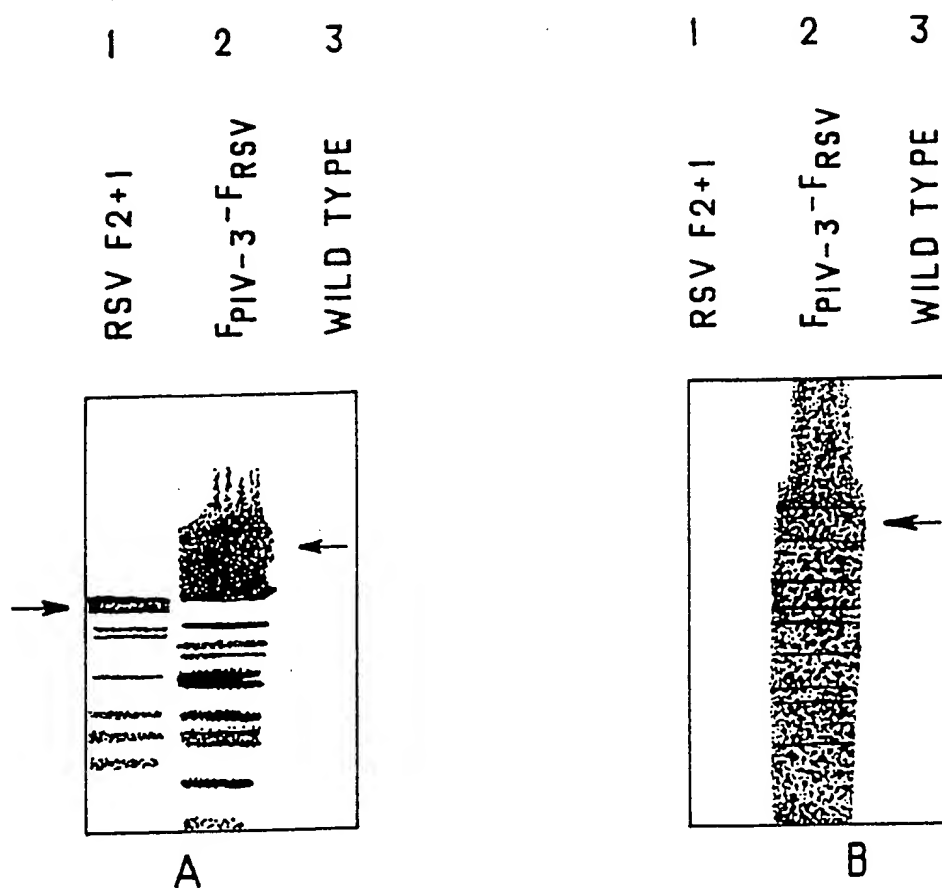
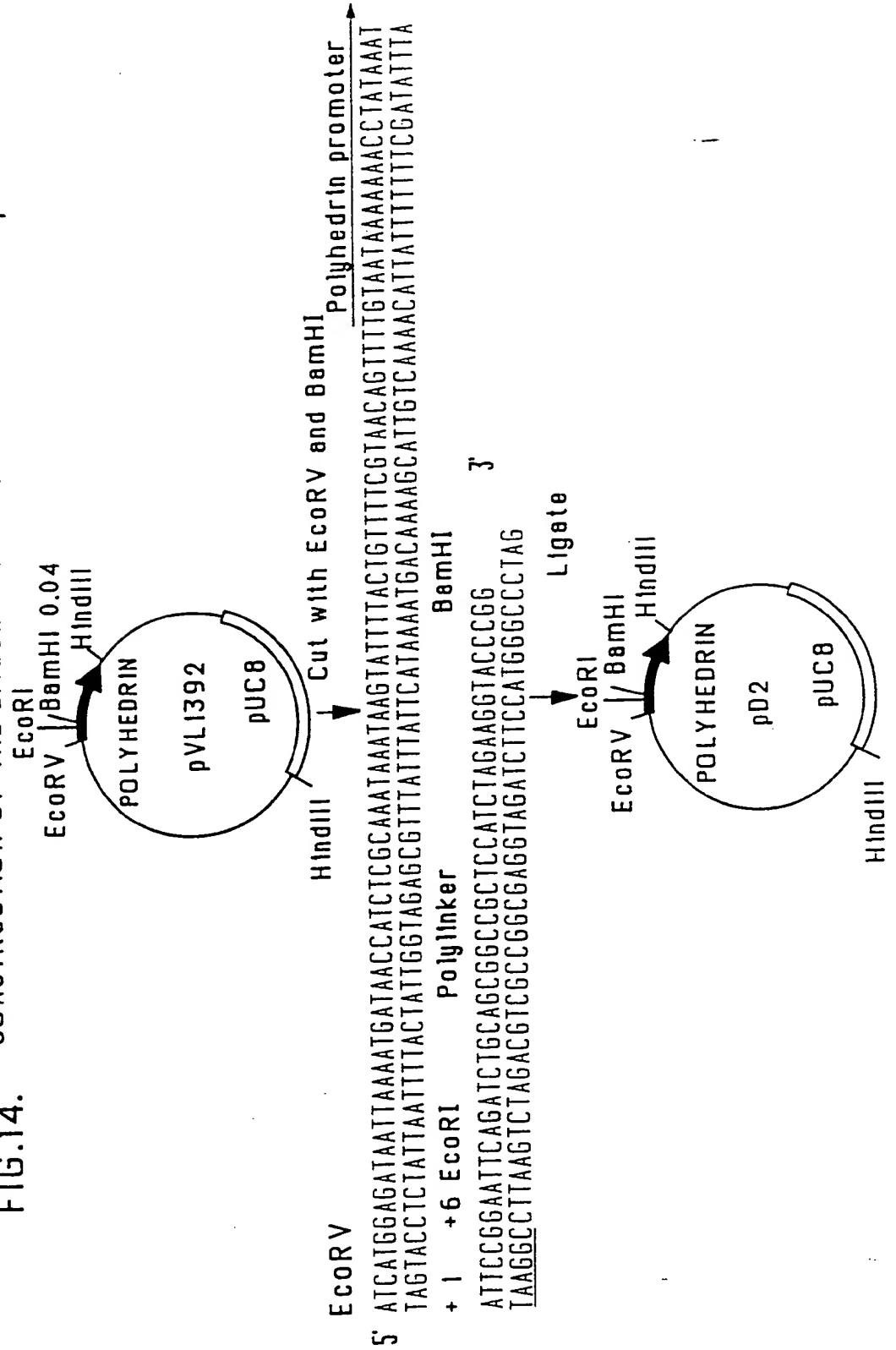


FIG 13 : Immunoblots of cell lysates from Sf9 cells infected with recombinant baculoviruses containing the truncated RSV F gene (Lane 1), the chimeric F_{PIV-3}-F^{RSV} gene (Lane 2) or infected with wild type virus (Lane 3) reacted with anti-F RSV Mab (panel A) and anti-F1 PIV-3 antiserum (panel B)

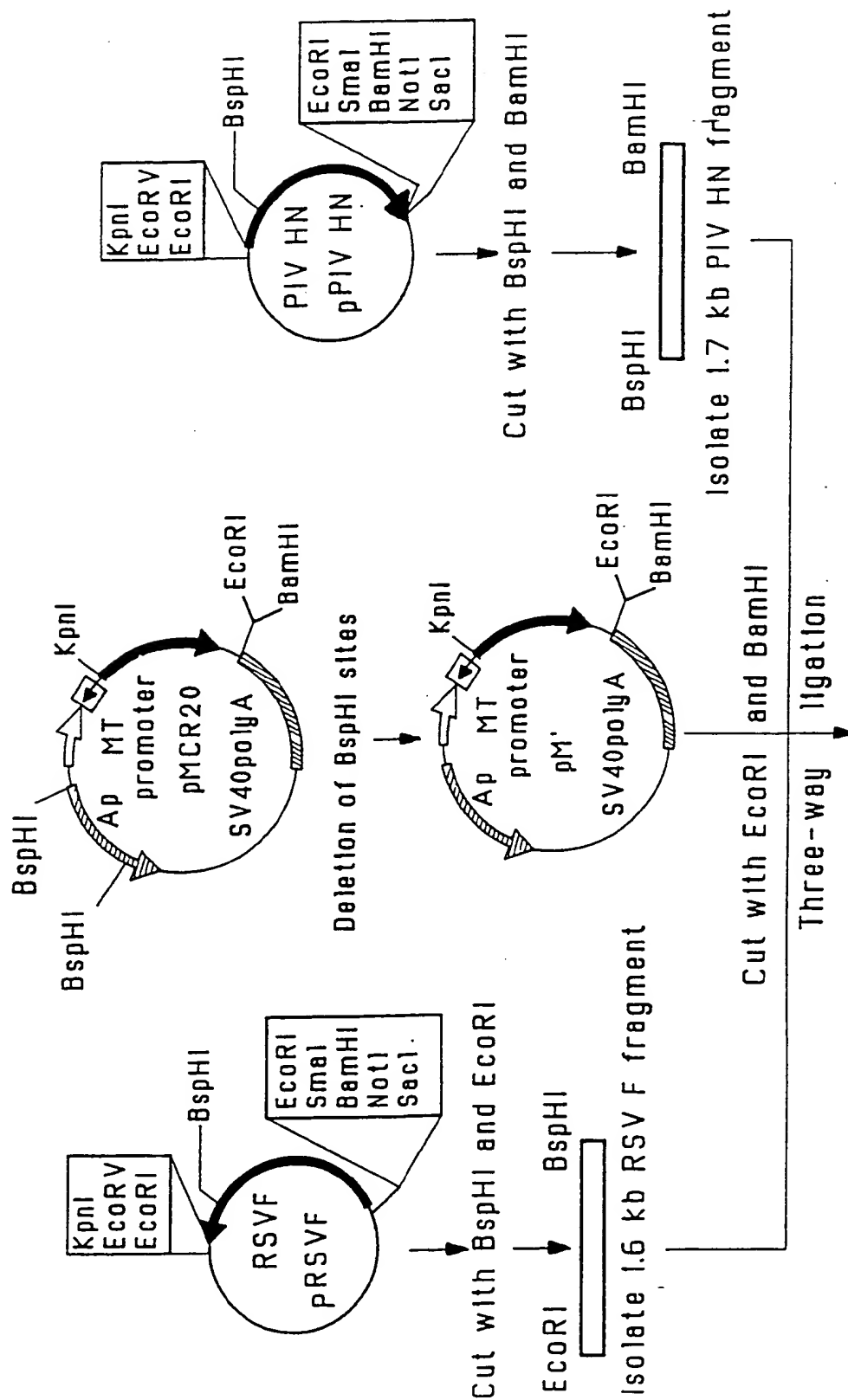
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FIG.14. CONSTRUCTION OF THE BACULOVIRUS TRANSFER VECTOR pD2



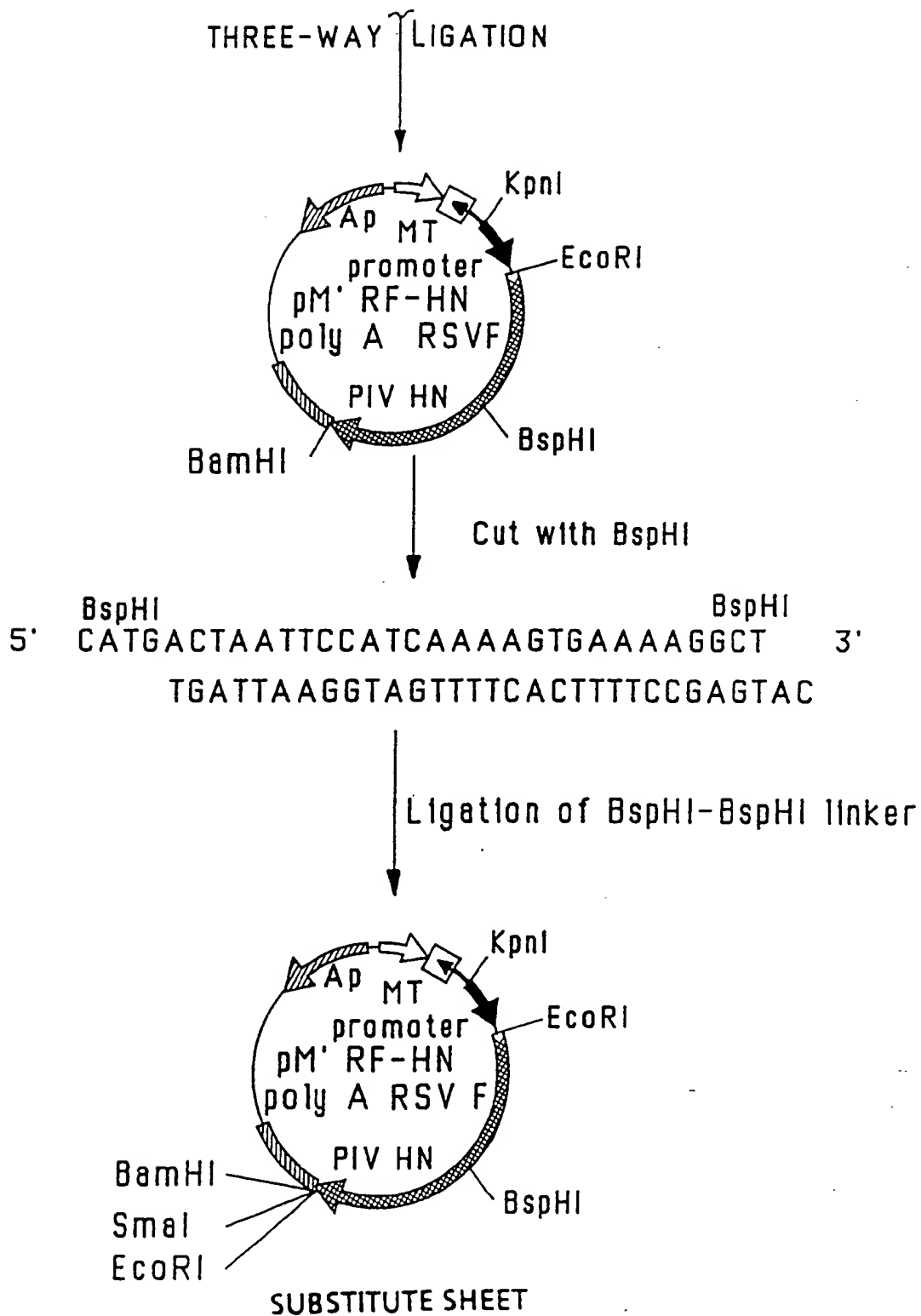
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FIG.15A. CONSTRUCTION OF THE $F_{RSV-HNPIV3}$ CHIMERIC GENE



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FIG.15B.



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FIG.16

SDS POLY ACRYLAMIDE GEL AND IMMUNOBLOTS OF
PURIFIED F_{RSV}-HN_{PIV-3} CHIMERIC PROTEIN

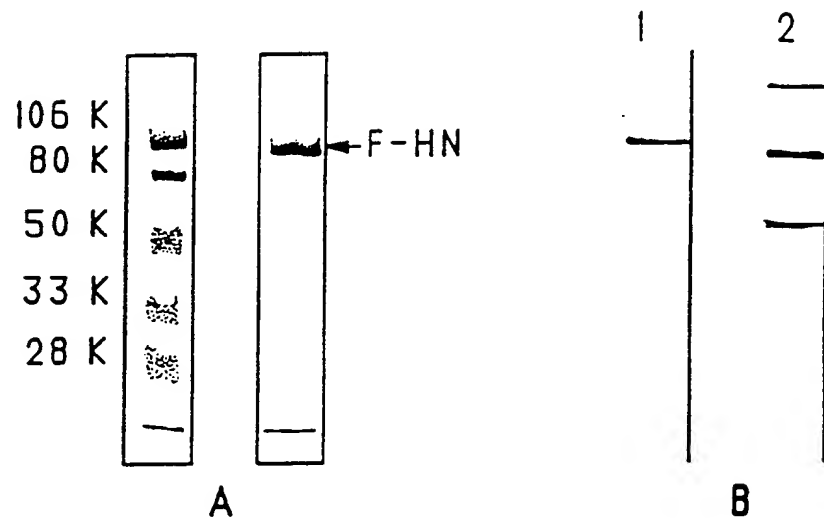
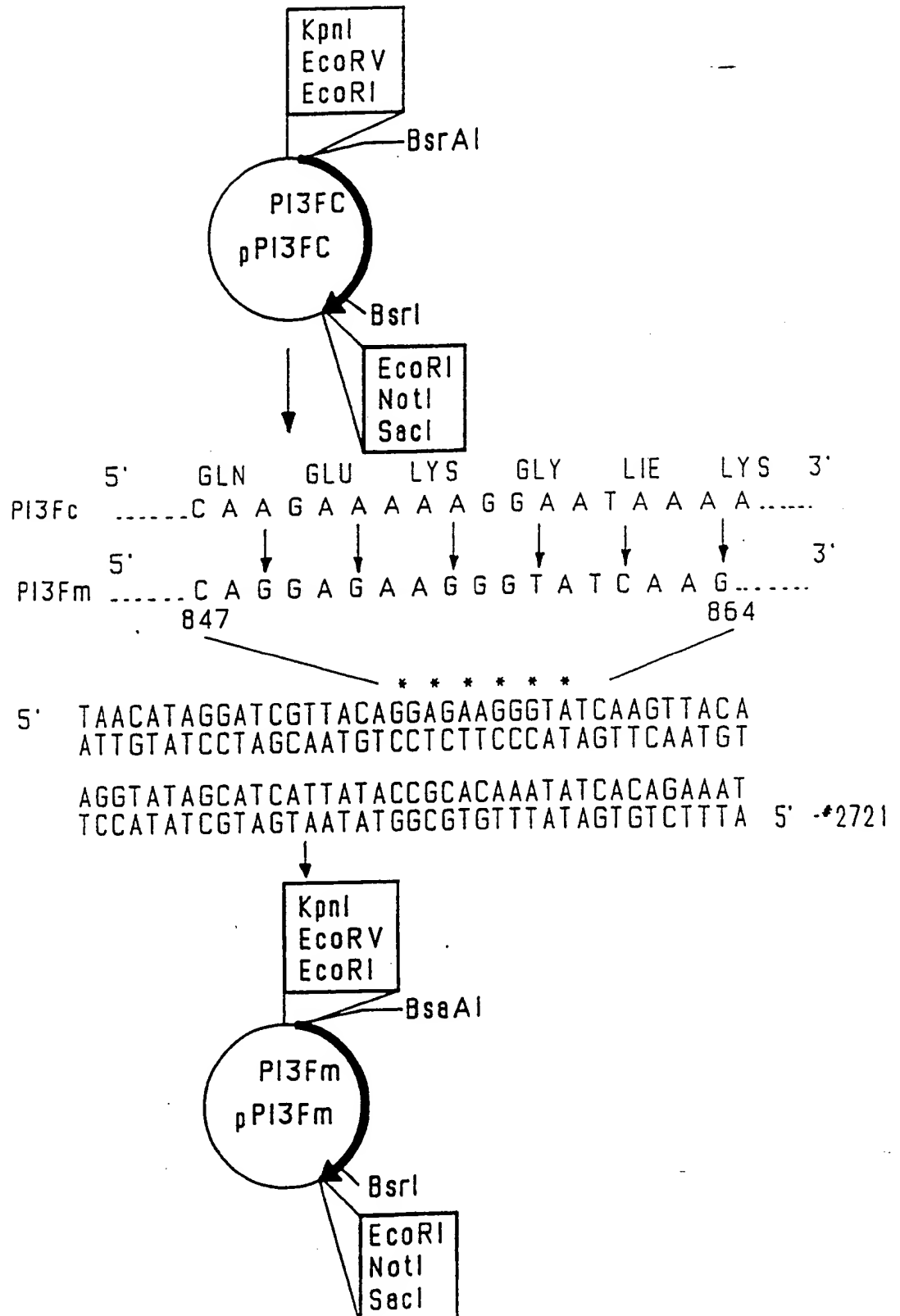


FIG 16 : A) Coomassie-stained SDS polyacrylamide gel of immunoaffinity- purified F_{RSV}-HN_{PIV-3}protein.

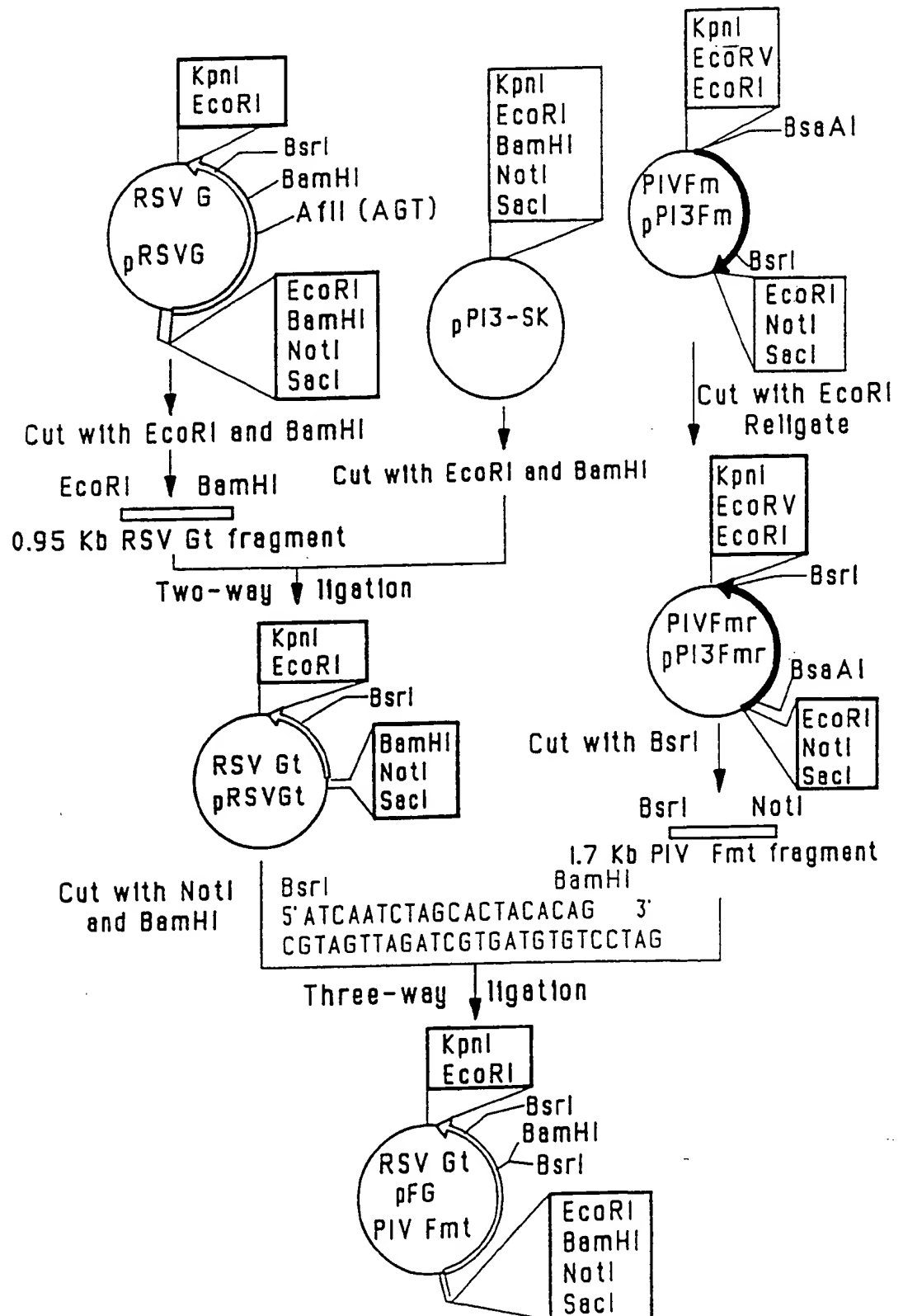
B) Immunoblots of F_{RSV}-HN_{PIV-3}protein reacted with an anti-F RSV Mab (lane 1) and anti-HN PIV-3 antiserum (lane 2)

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FIG.17. MUTAGENESIS OF THE PIV-3 F GENE



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FIG.18. CONSTRUCTION OF THE F_{PIV3}-G_{RSV} CHIMERIC GENE

INTERNATIONAL SEARCH REPORT

PCT/CA 93/00001

International Application No

I. CLASSIFICATION OF SUBJECT MATTER (If several classification symbols apply, indicate all) ⁶		
According to International Patent Classification (IPC) or to both National Classification and IPC		
Int.Cl. 5 C12N15/45; A61K39/155; G01N33/569		
II. FIELDS SEARCHED		
Minimum Documentation Searched ⁷		
Classification System	Classification Symbols	
Int.Cl. 5	C12N ; A61K ; G01N	
Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched ⁸		
III. DOCUMENTS CONSIDERED TO BE RELEVANT⁹		
Category ¹⁰	Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²	Relevant to Claim No. ¹³
X	J. VIROL. vol. 64, no. 8, 1990, pages 4007 - 4012 P. COLLINS 'O glycosylation of glycoprotein g of human respiratory syncytial virus is spaeified within the divergen ectodomain' see the whole document	1-11, 13, 16-26, 28, 29, 32-35, 39-47, 53
X	MOL. CELL. BIOL. vol. 8, no. 4, 1988, pages 1709 - 1714 S. VIJAYA ET AL. 'Transport to the cell surface of a peptide sequence attached to the truncated C terminus of an n-terminally anchored integral membrane protein' see page 1713	1-4, 6, 16-21, 28, 32-36, 39-43, 48-54, 56-58
<p>¹⁰ Special categories of cited documents:</p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.</p> <p>"&" document member of the same patent family</p>		
IV. CERTIFICATION		
Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report	
13 MAY 1993	05. 05. 93	
International Searching Authority	Signature of Authorized Officer	
EUROPEAN PATENT OFFICE	SKELLY J.M.	

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		
Category *	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
Y	WO,A,8 910 405 (THE UPJOHN COMPANY) 2 November 1989 cited in the application see the whole document ----	1-58
Y	WO,A,8 905 823 (THE UPJOHN COMPANY) 29 June 1989 cited in the application see the whole document ----	1-58
A	J. GEN. VIROL. vol. 70, 1989, pages 2637 - 2644 R. BRIDEAU ET AL. 'Protection of cotton rats against human respiratory syncytial virus' cited in the application ----	
A	J. GEN. VIROL. vol. 70, 1989, M. WATHEN ET AL. 'Characterisation of a novel human respiratory syncytial virus chimeric FG glycoprotein' cited in the application -----	

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CA93/00001

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☒ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
Remark: Although claims 54-56 are directed to a method of treatment of (diagnostic method practised on) the human/animal body the search has been carried out and based on the alleged effects of the compound/composition.
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
- ☐ No protest accompanied the payment of additional search fees.

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO.

CA 9300001
SA 68995

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information. 13/05/93

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO-A-8910405	02-11-89	AU-B- 611784	20-06-91
		AU-A- 3197589	24-11-89
		CA-A- 1306709	25-08-92
		EP-A- 0413695	27-02-91
		US-A- 5169628	08-12-92
WO-A-8905823	29-06-89	AU-A- 2785089	19-07-89
		DE-A- 3878468	25-03-93
		EP-A, B 0396563	14-11-90
		US-A- 5194595	16-03-93

EPO FORM P0479

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

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